MECHANICAL ENGINEERING

November 1939

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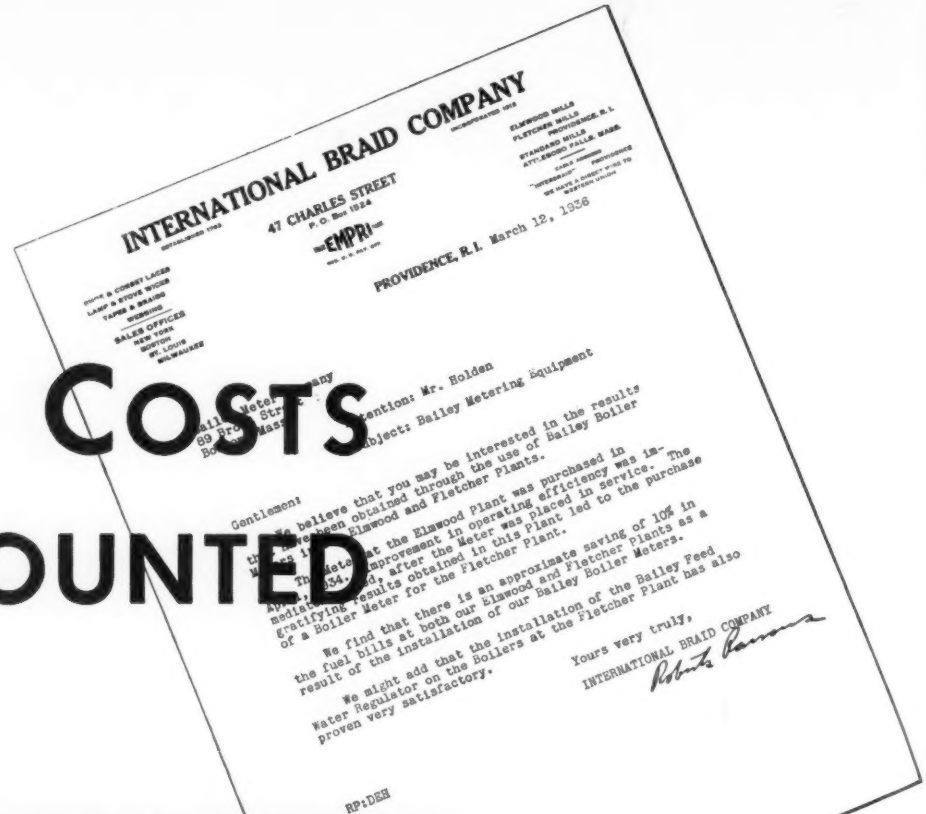
INTERNATIONAL BRAID COMPANY

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PROVIDENCE, R.I. March 12, 1936

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Attention: Mr. Holden
Subject: Bailey Metering Equipment

Gentlemen:

We believe that you may be interested in the results that have been obtained through the use of Bailey Boiler Meters in our Elmwood and Fletcher Plants.

The Meter at the Elmwood Plant was purchased in 1934. Improvement in operating efficiency was immediately noted, after the Meter was placed in service. The gratifying results obtained in this Plant led to the purchase of a Boiler Meter for the Fletcher Plant.

We find that there is an approximate saving of 10% in the fuel bills at both our Elmwood and Fletcher plants as a result of the installation of our Bailey Boiler Meters.

We might add that the installation of the Bailey Feed Water Regulator on the Boilers at the Fletcher Plant has also proven very satisfactory.

Yours very truly,
INTERNATIONAL BRAID COMPANY

RP:DEH

Bailey Boiler Meter installed on 394 h. p. oil fired boiler at Fletcher Plant of International Braid Co., Providence, R. I.

A SAVING of 10% in fuel costs has been realized by International Braid Co. of Providence, Rhode Island, since Bailey Boiler Meters were installed. • If you are operating boilers of 100 h. p. or more, 10% discount on your fuel costs represents a saving which is well worthwhile. • Additional examples of actual savings effected by Bailey Boiler Meters will be furnished upon request. Send for a set of reports of tests made in typical power plants where coal, gas and oil fired units range in size from 100 h. p. up.

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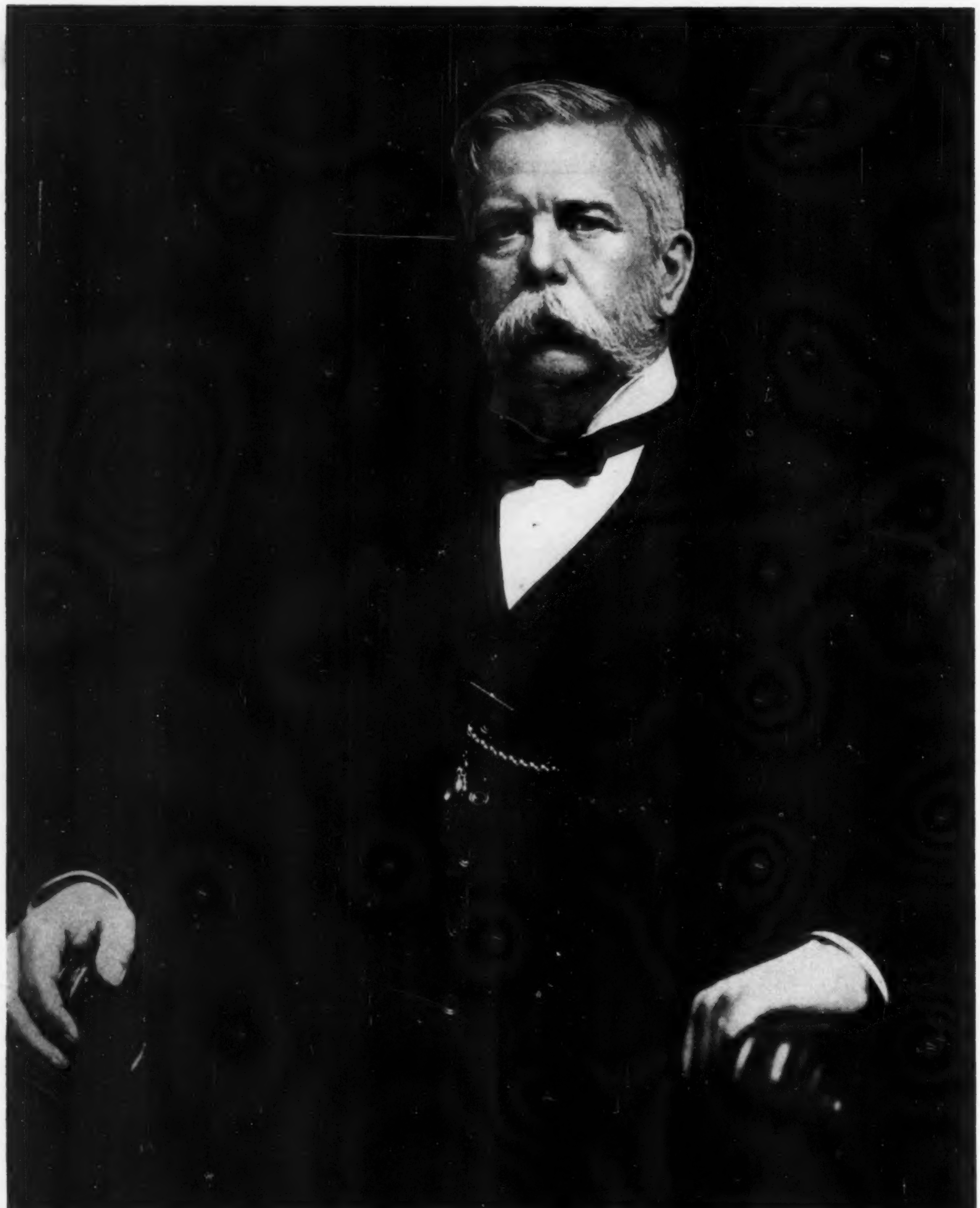


Geo. Westinghouse

(The Ninetieth Anniversary of the birth of George Westinghouse will be commemorated at the Annual Meeting of The American Society of Mechanical Engineers, November 30–December 4, 1936. See pages 751–754.)

MECHANICAL ENGINEERING

Volume 58
No. 11

November
1936

GEORGE A. STETSON, *Editor*

Deadline—January 1, 1937

IN THE A.S.M.E. News section of this issue will be found excerpts from the annual report of the engineering examiners of the State of New York in which attention is particularly directed to the expiration, on January 1, 1937, of the so-called "grandfather" clause of the state's engineer license law, which permits the board to exempt from written examination a certain class of applicants.

It would be a neglect of duty on the part of Mechanical Engineering not to emphasize to its readers resident in New York State or those who intend to practice engineering in it the implication of this notice. For after January first the engineering examiners of the state will be compelled by the law to require applicants for license to practice engineering to take the written examination. To take advantage of the "grandfather" provision of the New York State law engineers should act at once.

A.S.M.E. Annual Meeting Papers

COMPLAINTS are sometimes heard to the effect that papers for presentation at meetings of The American Society of Mechanical Engineers are not preprinted. Undoubtedly, many of these complaints are the result of a misunderstanding of present publication procedure.

Members of the Society receive every month the Transactions and Mechanical Engineering. In issues of these publications that appear immediately in advance of a meeting are printed as many of the papers to be presented at that meeting as are received in time to be included. For example, five of the 1936 Annual Meeting papers will be found in this issue. Our December issue, which will be in the mails before the meeting, will contain the eight papers that comprise the corrosion of metals symposium, a notable feature of the 1936 technical program. The November issue of Transactions, mailed to all members on November 10, will contain 20 other papers. With the exception of a few papers to be presented by title only, and others assigned to later issues of Mechanical Engineering and Transactions, some of which were received too late for our issues, every paper will have been made available to all members. It is expected that printed copies of some of the papers that were received too late for prepublication will be available before the meeting and hence may be studied as a basis for discussion. Members wishing to discuss Annual Meeting papers, therefore, should consult the technical program on pages 751 to 754 of the A.S.M.E. News section of this issue where are noted the Society publications in which the papers will appear.

It is the policy of the Society to publish in advance of the meeting every paper presented for public discussion. In carrying out this policy the program-making agencies of the Society exert every reasonable pressure on authors to get manuscripts in time for prepublication. In the interests of good meetings and worth-while discussions, members who write papers are urged to prepare them well in advance of the dates on which they are due.

E.C.P.D. Makes Progress

ENGINEERS who have the welfare of their profession at heart will be encouraged to learn of the substantial progress made by the Engineers' Council for Professional Development and reported at its Annual Meeting held in New York on October 6. In the A.S.M.E. News section of this issue will be found a report on the officers elected and another covering the list of undergraduate engineering curricula accredited by the Council in the New England and Middle Atlantic States. Further details of reports of the Council's major committees will probably be featured in later issues, for in work of such importance as this the widest publicity and opportunity for free discussion is essential.

Any one who was privileged to attend the Council's meeting could not help but conclude that its affairs are under competent and intelligent direction. The engineers who represent the societies which make up the Council and who serve on its committees are well and favorably known as men of high standing and attainment. It is creditable to the profession that they are applying their talents and the engineering method of analysis to the problems that confront the Council. Here is an excellent example of what engineers can do in nonengineering fields; for it must be granted that the Council is concerned with human rather than technical engineering questions.

It is a pleasant duty to report favorably on the progress that E.C.P.D. has made so far. The Council's work is of a character that is easily done badly by bunglers and short-sighted persons. Any less harmonious a combination of idealism and business-like practicability than the Council has shown to date would be likely to discredit a worthy cause and bring reproach rather than honor to the engineering profession.

By strict vigilance the high quality of the Council's

work can be maintained. When the pioneering phase is safely passed it will be the duty of the participating societies to appoint as representatives men who have not had the benefit of the discussions in which the program and policies of the Council were conceived and who must bring to it the vigor of new ideas and the determination to maintain for it the high reputation it now holds. Only as these representatives are men of broad vision can the Council continue to progress. But this vision must be truly broad, for it must not be forgotten that the Council represents engineering and the practicing engineer. Such a sensitiveness to the profession as representatives on the Council require is not their responsibility alone. It depends also upon the attitude and opinions of members of the engineering societies, and for this reason no engineer can be indifferent to what the Council is doing.

Learning to Live With Science

ONE of the principal advantages to a reader on this side of the Atlantic of the presidential address delivered by Sir Josiah Stamp at the Blackpool meeting of the British Association for the Advancement of Science is the quality of objectivity that it derives from not being a discussion of conditions in this country. True, Sir Josiah mentions some of our problems (he seems particularly obsessed with the idea that our Constitution may be responsible for a certain amount of scientific frustration, although he does not bring out the fact that the document itself provides part of the cure for which his own solution offers the remainder), but his thoughtful analysis of the impact of science on society is just academic enough to remove consideration of it from the realm of our national politics.

Sir Josiah is concerned with change, its increasing tempo, and the impact of science on society as a major factor in that change. "The attitude of mind of our order," he says, "may be either that change is an interruption of rest and stability, or that rest and stability are a mere pause in a constant process of change." Public (and personal) confusion over these two attitudes of mind hark back to the dawn of civilization and are more than ever at work today; for, as is made clear, the effects of science are to produce a headlong precipitateness in change itself with a complex assortment of conflicting interests which are none the less desirable because they appear to be antagonistic. For example, he says at one point, "The very social machinery which is set up to facilitate change or to soften dislocation, aggravate the evil," and at another (speaking of value equilibrium), "At this moment when elasticity is most wanted, stability leading to rigidity becomes a fetish."

Some paragraphs are devoted to a discussion of responsibility for preparing society for the impact. Here the dilemma is stated "that the training of the scientist includes no awareness of the social consequences of his work, and the training of the statesman and administrator no preparation for the potentiality of rapid scientific advance and drastic adjustment due to it, no prevision of the technical forces which are shaping the society in which he lives. The crucial impact is nobody's business." And as to this prevision itself, "planning, as such . . . . does not provide automatically the secret of correct prevision in scientific innovation."

Much attention is directed to the effect of scientific innovations on employment and on industrial and technological obsolescence. Many difficult points are raised that have humane as well as economic implications. Who shall bear the cost of change? "What shall it profit a civilization if it gain the whole world of innovation and its victims lose their souls?" And suddenly, the emphasis shifts from uneconomic rapidity to improvident tardiness in introducing scientific innovations. Once more we are back to the fact that "our attitude of mind is still to regard change as the exceptional and rest as the normal."

Sir Josiah does not dodge the issue, and his suggestion is bold enough to be exciting, for "now we must consider modifying the nature of man to meet impact." This turns out to be less of a counsel of despair than one would imagine. "If the impact of science brings certain evils they can only be cured by more science." *Medice, cura te ipsum!* "Additional financial resources should be applied more to the biological and humane sciences than to the applied physical sciences, or possibly, if resources are limited, a transfer ought to be made from one to the other." For "unless progress is made in these fields which is comparable with the golden ages of discovery in physics and chemistry, we are producing more problems for society than we are solving." And so here we have the conclusion of the whole matter (and of the address), "We have spent much and long upon the science of matter, and the greater our success the greater must be our failure, unless we turn also at long last to an equal advance in the science of man."

Successful living with science, then, demands the broadest development of all departments of science, and the education of enough persons to insure practicable results. The lesson for the engineer is not less attention to the applied sciences in which he works but a keener understanding of the ways by which his own activities may be made more beneficial.

J. B. Patterson

AS WE go to press word comes of the sudden death of J. B. Patterson, of Park Ridge, Ill., for 11 years Midwest Representative of Advertising Sales of The American Society of Mechanical Engineers. During the past year Mr. Patterson also served the Society as its representative in the Midwest Office, Chicago, Ill. Geographically far removed from members of the Society's headquarters staff, Mr. Patterson labored none the less zealously in behalf of the Society. Through his services to the publications and the Society he won for them many supporters.

The STEAM TURBINE *in the* UNITED STATES

I—Developments by the Westinghouse Machine Company

By EMIL E. KELLER and FRANCIS HODGKINSON

THE WESTINGHOUSE MACHINE COMPANY of Pittsburgh, Pa., was incorporated in 1880, and commenced the building of the well-known Westinghouse single-acting, high-speed engine, following the designs proposed by Mr. Herman H. Westinghouse.

In 1893 Mr. George Westinghouse purchased much of the outstanding stock, and thereby acquired some 90 per cent of it. His purpose was to aid the Westinghouse Electric and Manufacturing Company, which had been incorporated in 1886, in the exploitation of its alternating-current generators by the development of suitable steam engines.

DEVELOPMENTS IN STEAM ENGINES AND ALTERNATING-CURRENT PRACTICE PRECEDING INTRODUCTION OF STEAM TURBINE

The development included the introduction of a flexible coupling, by means of which the generator could be directly connected to the engine. The torque was transmitted through springs in the coupling, thus providing the flexibility incidental to the use of belts. This led to the elimination of belts, which had, up to that time, been generally employed.

A further development was the introduction of the single-weight inertia governor, an invention of Frank M. Rites. By its means the angular speed variation during one revolution was expected to be reduced with a given MV^2 of the flywheel, and a general improvement in the speed regulation of the engine was introduced. This led to the abandonment of the spring flexible coupling, and the generator rotor was pressed on to an extension of the engine crankshaft, with satisfactory results.

THE CHICAGO WORLD'S FAIR, 1893

By 1892 high-speed steam engines had been constructed in capacities up to about 250 hp, when Mr. Westinghouse secured the contract for furnishing the power and lighting for The World's Fair to be held in Chicago in 1893. For this purpose six 1000-hp, two-cylinder, compound, single-crank, steeple engines were constructed under the direction of Frank M. Rites. Each engine drove two 375-kw, 200-rpm, 60-cycle, single-phase, alternating-current generators, the armatures of which were pressed onto an extension of the engine crankshaft, but keyed in a position so that two-phase current for the operation of polyphase motors could be obtained from the two generators. Six similar generators were belt-driven by sundry engine exhibits.

The performance and reliability of these generating sets proved good in spite of their having a greater capacity than any sets built up to that time. At the conclusion of the Fair they operated for several years in power stations in Paris, New York, and Baltimore.

Contributed by the Joint Division on Engineering History and the Power Division for presentation at the Annual Meeting, Nov. 30–Dec. 4, 1936, of The American Society of Mechanical Engineers.

The World's Fair installation was carried out under the direction of Emil E. Keller, who had, for some years, been identified with Westinghouse power-station construction throughout the Middle West. Following the Fair he was invited by Mr. Westinghouse to go to Pittsburgh as vice-president and general manager of the Westinghouse Machine Co.

EARLY NEGOTIATIONS WITH SIR CHARLES PARSONS

In 1895, the work of the Hon. Charles Algernon Parsons in the commercial development of a reaction form of steam turbine, which began in 1884, excited interest in the United States. This particularly interested Mr. Westinghouse, who had already experimented with some forms of displacement rotary engines, but with no great success as concerns efficiency. He and his associates sensed that electric generators would be simplified and be less costly if they could be operated at higher rotative speeds than was possible by means of reciprocating engines. They thought that the Parsons turbine might meet these ideals, and that if it proved reliable and reasonably efficient, it must displace, in time, the slower-running reciprocator.

In this year (1895), following a single interchange of letters, it was indicated that Sir Charles Parsons was willing to consider a license agreement with the Westinghouse Machine Co. Thereupon Mr. Westinghouse instructed Vice-President Keller to proceed to England to investigate this type of turbine. The instructions to Keller were characteristic of the foresight, acumen, and ability to delegate authority on the part of George Westinghouse. His instructions were that if Keller saw value in this development, he was to acquire the American rights in some form or other, and to pay whatever consideration he thought proper. This resulted in an exclusive license agreement's being consummated in the latter part of 1895 for the manufacture and sale of the Parsons steam turbines in the United States exclusive of their application to marine propulsion.

At that time the steam turbine, as a practical machine, was comparatively unknown in the United States, although in that year The New York Edison Co. imported two Swedish-built 300-hp, De Laval, single-disk turbines, De Laval having commenced his development in 1888. There was, however, some turbine development in the United States much earlier than that of either Parsons or De Laval. Between 1833 and 1836 Wm. Avery, of Syracuse, built a number of "Hero" type reaction steam turbines that were principally employed for driving sawmills. In one instance the turbine was reported to be more economical of fuel than the reciprocator it replaced. It was reported by Professor Sweet that in 1836 one of these was employed to propel a locomotive, but its life ended in a ditch near Newark, N. J. These turbines were said to be objectionable because of noise and erosion on the back of the arm operating in the stream from the opposite nozzle. Later J. H. Dow built a number of ingeniously constructed radial-flow turbines

that were principally employed by the Navy Department for spinning the flywheels of Howell torpedoes. In the early nineties there were several small DeLaval single-disk turbines operating at 20,000 to 30,000 rpm, driving cream separators through reduction gears. A small electric generating set had been exhibited at the World's Fair in 1893.

EARLY DEVELOPMENT BY PARSONS IN ENGLAND

Notwithstanding all of the foregoing, it may be properly said that the early work of Parsons began a great renaissance in the steam-turbine art.

By 1895 approximately 400 Parsons turbines had been built in England, ranging in capacity up to 500 kw; most of them having been designed for noncondensing operation. Three small power stations at Newcastle, Cambridge, and Scarborough had been built by the Parsons Company and were equipped with condensing turbines of about 75 kw capacity. A number of 350-kw, 3000-rpm, noncondensing, alternating-current generating sets had been installed in the Manchester Square station of the London Electric Supply Company. This station was

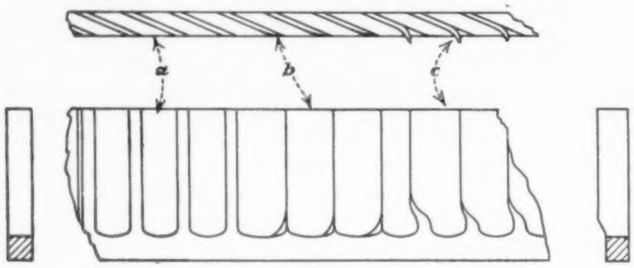


FIG. 1 EARLY METHOD OF MAKING TURBINE BLADES BY SAWING SLOTS IN A BRASS STRIP

originally equipped with Willans engines, but the operating company received an injunction on account of vibration that resulted from a peculiar soil condition and was transmitted over a large area of a densely populated district. Some Westinghouse single-acting engines were installed with no particular diminution of the difficulty. The installation of the Parsons turbines permitted the station to be operated.

The experimental turbine-driven ship, the *Turbinia*, had been built and many sea trials had been carried out, which were quite unsuccessful in so far as ship performance was concerned. It was not until 1896 and 1897, after a turbine comprising three compounded elements, each driving a propeller shaft carrying three propellers, had been substituted for a single complete-expansion turbine with a single propeller that success was attained. By model experiments, the difficulty was shown to have been due to cavitation, a phenomenon that was scarcely, if at all, known in those days. At the Naval Review at Spithead in 1897 the *Turbinia* caused a sensation in naval circles. The speed reached was $32^3/_4$ knots, which was unprecedented for a vessel only 100 ft in length.

RESULTS OF KELLER'S NEGOTIATIONS WITH SIR CHARLES PARSONS

It seemed evident that if the Westinghouse Company should undertake the exploitation of steam turbines in the United States, it should have the assistance of some one experienced in such work, at least during the building of a few of the early turbines. E. E. Keller, during his negotiations for the license agreement, had become acquainted with Francis Hodgkinson, an engineer in the employ of the Parsons Company. This contact led Mr. Keller to make a request to Sir Charles that Hodgkinson should be permitted to join the engineering force of the Westinghouse Machine Company. Sir Charles was at first reluctant to release Hodgkinson, but finally consented, recognizing that if the turbine venture was to be successful in the United States, there was need of some one with knowledge and experience in the theory and technical detail of turbine design, including machine-shop operations peculiar to turbines, as well as the problems of installation and operation.

Mr. Hodgkinson had been associated with Sir Charles Parsons since 1886 when steam turbines were in their earliest stages of development, except for four years when he served as an engineer officer in a foreign navy and held sundry engineering jobs in South America.

The license agreement provided that a turbine generating set be shipped to Pittsburgh to serve as an example of construction. The largest set that was available for prompt shipment was selected. The turbine was of the reaction type and drove a 150-kw, single-phase, 1000-volt, 5000-rpm, 100-cycle, alternating-current generator. On arrival it was promptly put in operation on the company's testing floor, and was subjected to tests under the mediocre operating conditions of the works, particularly those of condensing facilities. The full-load performance approximated 42.6 lb of steam per kwhr with 120 lb per sq in. (gage) wet steam and a 24-in. vacuum.

Having odd frequency and voltage, this machine was of no commercial value, but it served its purpose for demonstration and for a basis of engineering discussion. A year or two later it was presented to Cornell University where it operated for some time in the engineering laboratory of Sibley College. Subsequently, the armature burned out but no repairs were attempted because of its useless electrical characteristics. It was then relegated to the college basement. Later a resting place was found for it in the Museum of Peaceful Arts in New York, which has since become the Museum of Science and Industry.

FIRST TURBINES BUILT BY THE WESTINGHOUSE MACHINE COMPANY

The Westinghouse Machine Company began its turbine activity in the spring of 1896. It had been awarded a contract for a 120-kw, 180-volt, direct-current generating set for the Nichols Chemical Co., of Long Island City. Inasmuch as Parsons had built 310-kw, low-voltage machines at 3600-rpm and smaller machines for much higher rotative speeds, the Machine Company's engineers induced those of the Electric Company to design this generator for 5000 rpm. A commutator was arranged at each end of the armature, from which current was collected in parallel. Carbon brushes were first employed but during shop tests it was found that, because of the resistance of carbon, there was a condition of instability and all the current would flow from one or other of the commutators. This difficulty was overcome by adopting the Parsons practice and substituting brushes comprising a flat bundle of fine brass wires. Fair commutation was obtained and the machine was put in operation in the purchaser's plant. The commutation might have been regarded as satisfactory in England but it by no means measured up to the electrical standards of the United States. The field flux was low, and it was easy to supply new field coils, with which full voltage would be obtained at the reduced speed of 3600 rpm. However, the purchaser rejected the machine before this change could be accomplished, whereupon it was returned to East Pittsburgh where changes were made to the field coils and the machine was put in operation on the testing floor. It was useful for many years as an exciter for alternator tests. This was during a period before high-speed hydraulic brakes had been developed and when turbines were tested in combination with their generators.

The blading of this machine was embryonic. See Fig. 1. The blade passages were formed by sawing slots at an angle in a brass strip as at *a*. The flat blades thus formed were sharp-

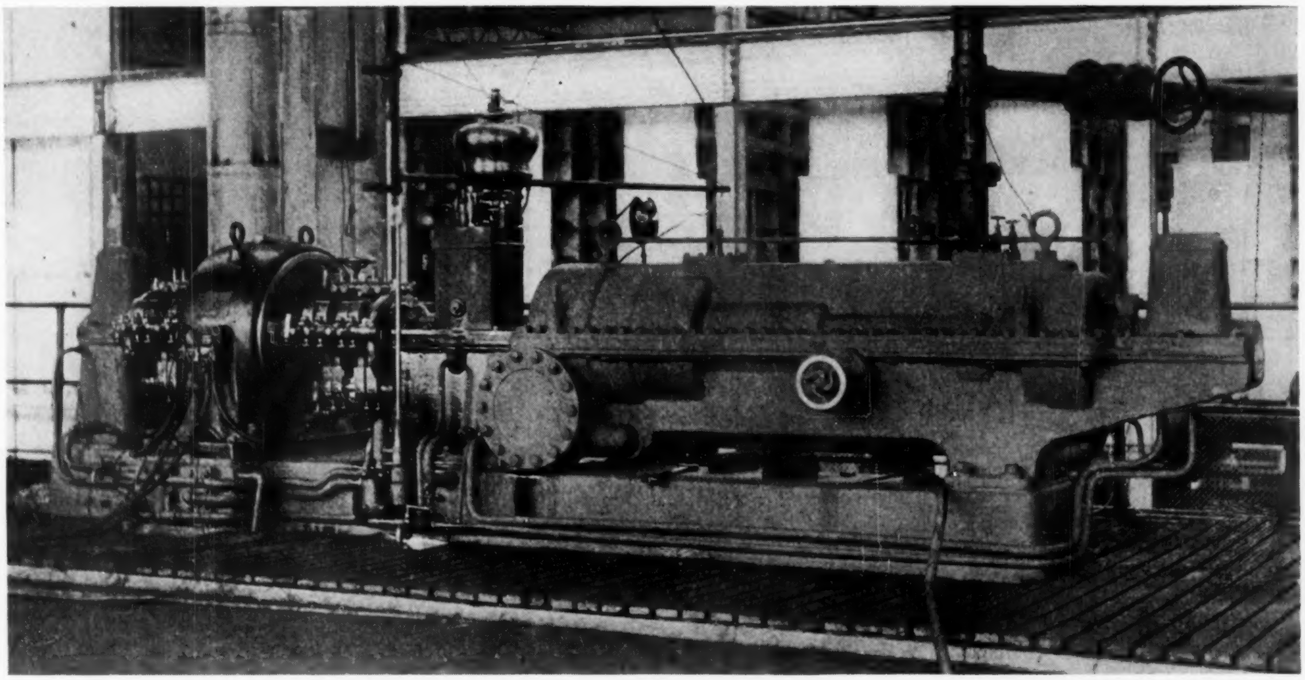


FIG. 2 FIRST PARSONS STEAM TURBINE BUILT IN UNITED STATES

ened at the entering edge by means of a hand-operated machine as at *b*. This edge was then crimped by another hand tool as at *c*. The whole strip was finally bent, set in parallel grooves, and calked.

At the time this machine was designed, all those built by Parsons had their speed regulated by means of an electric governor, which enabled the generator, whether alternating or direct current, to operate at constant voltage. The speed increased with increase in output, in accordance with the inherent voltage characteristics of the generator. Obviously, machines so regulated could not operate in parallel, and in England it was not expected that they would be called upon to do so. At that time only one or two pairs of belt-driven alternators had been paralleled in England. In Parson's practice the delicate impulses of a solenoid were transmitted to the regulating valve through an ingenious servomotor in the form of a steam relay. The lever mechanism between the solenoid and the relay was caused to oscillate some 100 to 250 times per minute by means of an eccentric geared to the turbine, so that steam was admitted to the turbine in puffs of longer or shorter duration, according to the load. The whole mechanism was continuously in motion, friction of rest was eliminated, and excellent regulation was attained, in spite of the minute solenoid impulses. The Westinghouse Company recognized the attributes of this steam-relay system of regulation but also the fact that all machines must be sensible of parallel operation. It merely substituted a flyball governor for the solenoid.

This, the first Parsons steam turbine built in the United States, after having served its usefulness as an exciter, was broken up and scrapped. It is to be regretted that its historical importance was not appreciated and that it was not preserved in a museum. A shop view of it is shown in Fig. 2. The steam consumption was by no means bad, considering the capacity, operating conditions, and the state of the art. With wet steam at 160 lb per sq in. (gage) and a 26.5 in. vacuum, tests showed for full load, three-quarter load, and half load, steam consumptions of 29.2, 31.6, and 35.9 lb per kwhr, respectively.

The construction of the machine for the Nichols Chemical Company was immediately followed by that of a 150-kw, 5000-rpm, noncondensing machine which, except for the proportioning of the steam path, was precisely similar. It was not sold and was finally scrapped after it had been useful in the works for some years for driving experimental apparatus requiring high speed.

From 1897 to 1899 the Westinghouse Machine Company's works was engaged in the manufacture of large gas engines and a few large reciprocating steam engines, which left little space for turbines. However, Mr. Westinghouse continued his interest in steam turbines, and during the interim some experimental machines, not of the Parsons type, were built under his direction. These were without improvement over the principles enunciated by Parsons. At that time further reason for inactivity was the fact that the steam turbine did not as yet enjoy much confidence among most engineers.

THE WESTINGHOUSE AIR BRAKE COMPANY'S TURBINES

In 1899, the Westinghouse Air Brake Co. discarded several single-acting engines that were used to drive line shafting through belts, and substituted a-c motor drives. A power plant which to begin with contained three 300-kw, 60-cycle, 440-volt, 2-phase, 3600-rpm turbine sets, was constructed to furnish the necessary energy. A prime reason for equipping the plant with turbines was to demonstrate their reliability and sufficiency.

The first generators were of the two-pole, revolving-armature construction. It was not long before some binding wires let go on two of them, and parts of the armatures went through the roof, fortunately, with no other damage. The generators were then rebuilt with revolving fields. This then became standard practice for turbine-driven alternators. The turbines were generous in capacity, so the new generators were designed for a 24-hr capacity of 400 kw, with 50 per cent overload for 1 hr.

A view of this plant is shown in Fig. 3. The turbine steam path comprised reaction blading, arranged on three diameters as shown by the longitudinal section of Fig. 4.

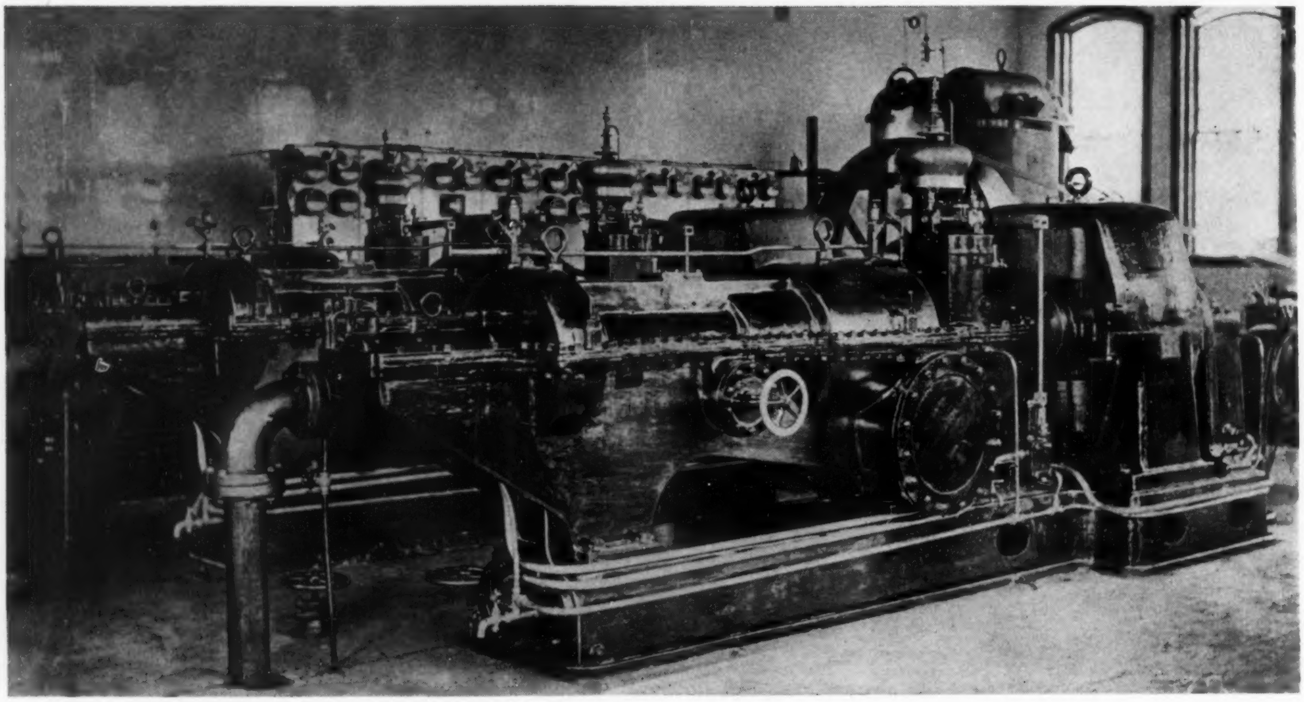


FIG. 3 TURBINE GENERATING SETS BUILT FOR WESTINGHOUSE AIR BRAKE COMPANY IN 1899

A new and more efficient form of blading, which shortly before had been developed by the Parsons Company, was employed for the first time in these machines. The blade sections were produced by drawing, as in a wire-drawing process; they were then cut to the desired length and some trivial serrations were stamped at the root ends. Packing pieces or spacers were similarly drawn, but were of a section complimentary to the blade section. The blades and packing pieces were alternately set in slightly dove-tailed grooves. The packing pieces were first compressed by stemming, so they filled the groove and pinched the blades. Then the edges of the groove were calked. The blading was drawn from an alloy known as "Delta" metal, a copper-zinc alloy containing a little iron. The packing pieces were made of about 0.30-carbon steel.

It will be noted that the blading was held merely by friction; nevertheless the fastening was reliable and this system was continued in practice for moderately stressed reaction blades until 1912. While there were numerous instances of blade breakage, there were few, if any, where blades failed because they were not securely held. Obviously, such a system could not serve with modern steam-temperature conditions.

Difficulties were experienced in obtaining from outside wire-drawing concerns the drawn blading material of the desired nonuniform section with the necessary sharp edges. The dies were made of a block of steel about $1^1/_4$-in. thick in which was an aperture appropriate to the blade section. Marvelous skill was exhibited in the making of these dies, but the suggestion that if the dies were split, they could be made both more cheaply and accurately, resulted in ridicule. It was not until the Westinghouse Company installed draw benches that accurate blading was cheaply produced. This kind of experience was repeated years later when attempts were made to purchase impulse-blade forgings from drop-forging concerns.

Shop tests carried out in 1899 on the first of the 300-kw Air Brake Company's turbines gave the following result:

Steam pressure, wet, lb per sq in. gage	135
Vacuum, in. Hg	$26^1/_4$
Output, kw	309.3
Steam rate, lb per kwhr	22.52

A later machine of precisely the same design, but tested under more favorable operating conditions, gave the following results on shop tests:

Steam pressure, lb per sq in.	150			
Superheat, F	100			
Vacuum, in. Hg	$26^1/_4$			
Output, bhp	264	445	593	759
Steam rate, lb per bhp-hr	14.48	12.87	12.05	12.06

The Air Brake Company's power station with its original equipment operated for some 25 years when it became expedient for the company to purchase its power requirements, and the plant was abandoned. Without canvassing the situation, the Air Brake Company broke up these turbines, at a time when various museums and institutions were begging for early examples of turbine constructions.

Sixty-six of these machines were sold later, with no material change in design. One of them, exhibited at the Louisiana Purchase Exposition in 1904, operated continuously and furnished energy during the whole period of the Exposition, a performance which in those days was regarded as an achievement.

CONDENSER PROBLEMS RAISED BY THE STEAM TURBINE

Early turbine progress was retarded in the United States because condensing apparatus capable of producing a high vacuum was not available. The facilities at the Westinghouse plant, even after it had moved to new buildings in East Pittsburgh in 1896, were not capable of producing a vacuum in excess of 23 or 24 in. Hg. Attempts to purchase better air pumps developed the fact that no manufacturer would guarantee better than 26 in. of vacuum and it was questionable, judging by the design, whether even that could be attained. Meantime a vacuum of 29 in. was not uncommon in European turbine practice. Because of this condition the Westinghouse engineers designed an air pump according to their own ideas,

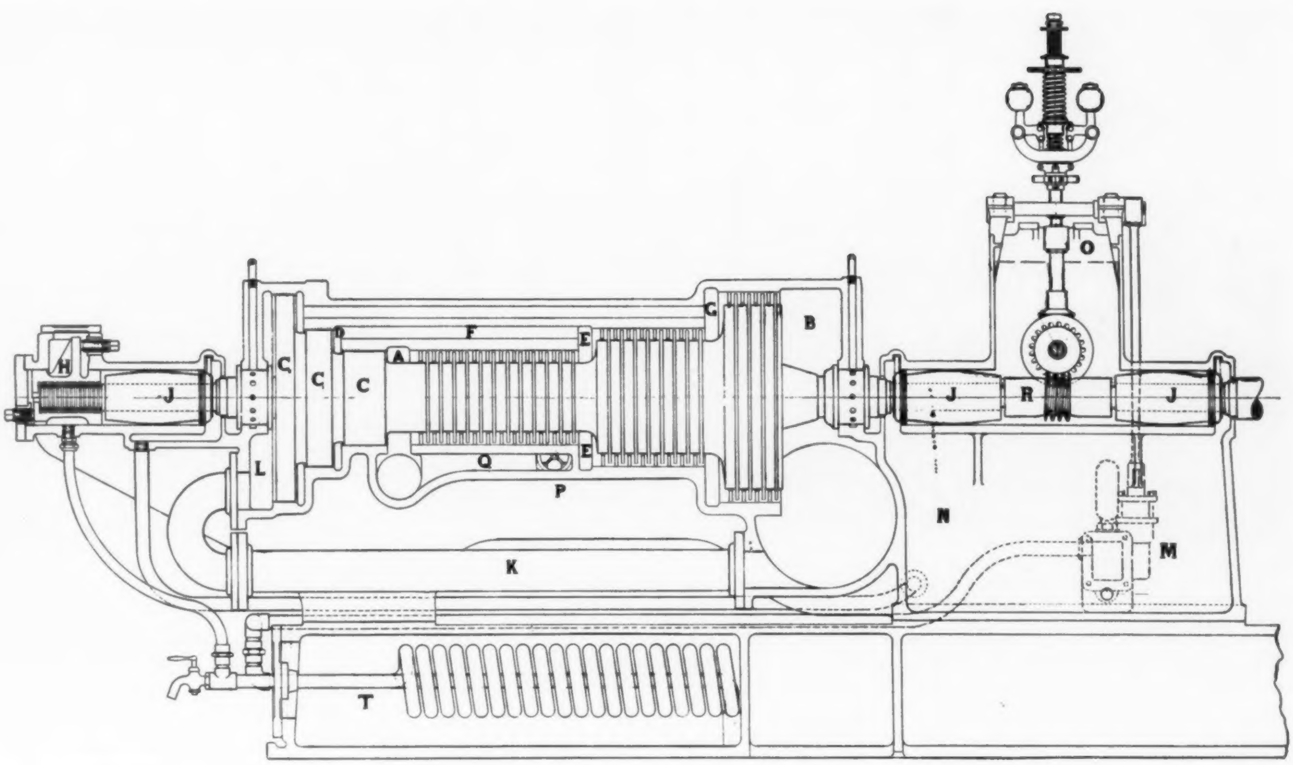


FIG. 4 SECTIONAL VIEW OF THE AIR BRAKE COMPANY'S TURBINE (REACTION BLADE PROPORTIONS NOT CORRECT)

somewhat elaborating the practice of C. A. Parsons & Co. This was a vertical wet-bucket pump provided with water seals. It was driven by the steam end of a standard air-brake pump. With a closed suction, a vacuum within a small fraction of an inch of the barometer could be readily maintained.

This condition of the condenser market led the Westinghouse Machine Company to design and build jet condensers for the Air Brake plant in 1899. In this case Parsons' practice was again somewhat followed. The injection water was admitted to chambers contiguous with the turbine exhaust nozzles, whence the mixture of injection and condensate was carried some 30 ft to the pumps. The pumps were arranged with a water-ejection plunger below and the bucket air pump above the point of water admission. The pumps were driven by a motor-driven crankshaft.

The vacuum realized in practice in the Air Brake Company's plant was probably higher than had been attained in connection with steam-power machinery in the United States. The lives of these condensers were short, however, because the water of Turtle Creek that was used for injection is largely drainage from soft-coal mines and is extremely acid. Both bronze and iron parts were rapidly dissolved. Some years later they were replaced by lead-lined barometric condensers.

By 1902 turbine business brought the need of a turbine erecting shop at East Pittsburgh, including adequate surface-condensing equipment for testing purposes. The Alberger Condenser Company had been recently incorporated, and was awarded the condenser contracts. The surface condensers were arranged to receive steam at the bottom, and air was removed from the top. This was novel in American practice; it was practically turning the conventional condenser upside down. A number of later installations were arranged similarly. The noncondensable vapors were removed by means of compounded, reciprocating, dry-vacuum pumps. This is believed to be among the first applications of separate dry-air removal to a condenser.

It was believed that the Alberger Company offered the optimum of condenser engineering of that day. At least it was the first to recognize the requirements of steam turbines. The test-floor condensers performed admirably, except for corrosion, which was the result of taking the circulating water from Turtle Creek.

It was not until 1907 that Mr. Westinghouse interested himself in steam-condenser problems when he acquired rights under the patents of Maurice LeBlanc, of France. This again was an example of engineering foresight on the part of Mr. Westinghouse, inasmuch as the engineers of the company saw, at that time, little of value in the LeBlanc proposals. Following 1908 a number of low-level jet condensers were sold in which the well-known LeBlanc air pump was employed for the removal of noncondensable gases. In 1911, the Westinghouse Company expanded its condenser business to include surface condensers, and since that time it has contributed in no small degree to improvement in design. It introduced the radial-flow principle in 1914. In 1913 it introduced the steam ejector for removing the noncondensable gases from either jet or surface condensers. The ejector was also a development of Maurice LeBlanc and is, in some form, in general use today.

THE 1900 HARTFORD TURBINE

A somewhat epoch-making turbine was supplied by the Westinghouse Company to the Hartford Electric Light Company in 1900. The Hartford Company has always been famous for its courage in installing novel machinery. Much later it was the first to install a machine operating under the principle of the mercury-steam cycle. The Hartford turbine was sold to have a capacity of 1500 kw. The design, however, was generous and it was later given a rating of 2000 kw. Mr. Westinghouse interested himself in the design, and somewhat radical features were introduced under his direction. The low speed of 1200 rpm was selected, and the whole expansion was carried

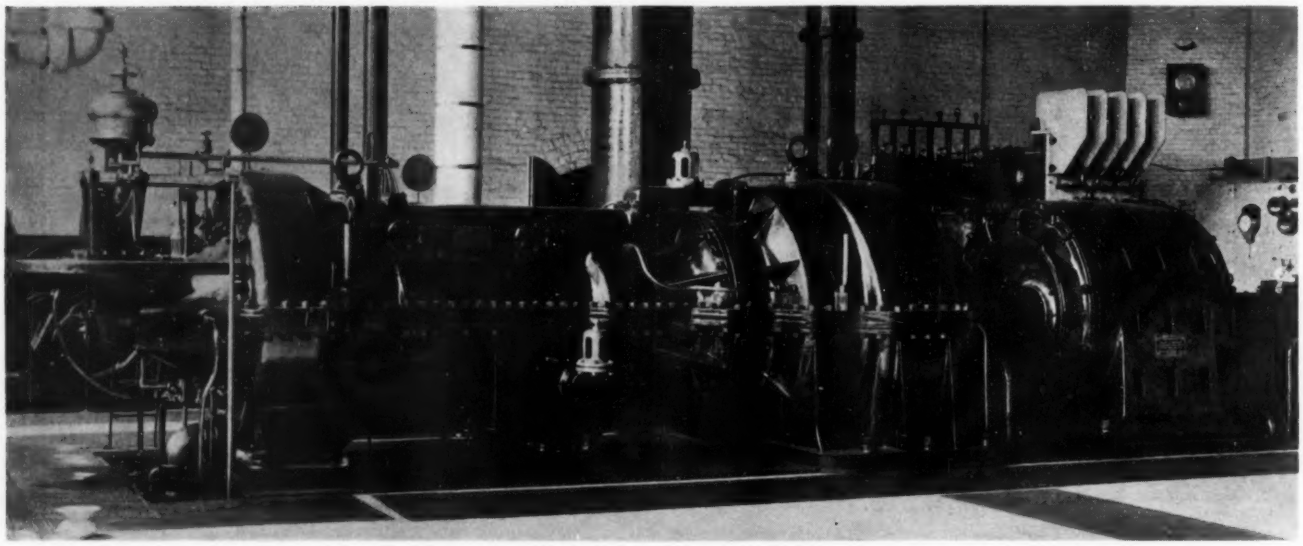


FIG. 5 TURBINE GENERATING SET BUILT FOR THE HARTFORD ELECTRIC LIGHT COMPANY IN 1900

out in a single casing. The capacity was several times greater than that of any other turbine built up to that time, which, combined with the low rotative speed, resulted in a ponderous machine of large physical dimensions. A view of it is shown in Fig. 5.

Tests carried out by the purchaser gave the following results.

Steam pressure, lb per sq in. (gage)	155
Superheat, F	41.6
Vacuum, in. Hg	26.9
Output, kw	1998.0
Steam rate, lb per kwhr	19.1
Engine efficiency, per cent	58.2

The machine, however, did not particularly shine from the standpoint of reliability. It was subject to considerable distortion; in fact it operated during the later period of its life without the last section of low-pressure blades because the corresponding low-pressure stationary and moving dummy strips could not be kept from contact with each other. Later experiences would have shown a way to overcome the difficulty. The machine was scrapped in 1908, after eight years of not entirely satisfactory operation. It, however, gave many valuable lessons.

THE TANDEM COMPOUND TURBINE

In the same year (1900) the Parsons Company built a highly successful 1000-kw turbine for the City of Elberfeld (Germany), in which the expansion was carried out in two separate cylinders, which were coupled tandem fashion to a single generator. This was followed by a circumstance that is not uncommon in engineering practice. Europeans were so impressed by the courage displayed by Mr. Westinghouse in constructing such a large-capacity machine in a single cylinder, and we in this country were so impressed by the simplicity of construction and the reliability that could be obtained by multicylinder construction, that each abandoned his own practice and adopted that of the other.

As a consequence the Westinghouse Company adopted the tandem-compound principle for turbines of capacity greater than 500 kw. Sixteen of them were installed between 1901 and 1904, having capacities ranging from 750 to 1500 kw. Those of 750 kw capacity operated at 1800 rpm, the others at 1200 or 1500 rpm, according to frequency. In some of them, intermediate reheating was tried by employing initial steam as the heating medium. This was a survival of cross-compound reciprocating-engine practice. The gain in efficiency did not justify the cost, so the reheaters were abandoned.

Because the steam expansion was divided between two cylinders, there was no need for compromise in the design of the steam path for mechanical reasons. These machines set a record for efficiency and were extremely reliable. Some of them were in service at least until two or three years ago.

One of them, rated at 1250 kw at 1200 rpm, supplied to the 59th Street station of the Interboro Rapid Transit Company in 1903, gave the following results.

Output, kw	Pressure, lb per sq in., gage	Superheat, F	Vacuum, in. Hg	Steam rate, lb per kwhr
1293.9	146.3	76.0	27.10	18.48
986.2	147.7	76.0	27.10	19.40
664.7	151.0	77.0	27.15	21.34
333.6	151.9	77.0	27.07	27.50

The full-load performance gives an engine efficiency of 59.6 per cent, including generator losses.

It seems absurd from a modern viewpoint to design such small capacities in compound fashion. The principle, however, is good and is employed today for machines of great capacity, specifically, when the combination of steam volume and rotative speed necessitates the multiple-flow principle for the last ranges of expansion, in order to avoid congestion.

DEVELOPMENT OF TURBINE BEARINGS

All of the foregoing early turbines were equipped with a flexible type of bearing which Parsons had found necessary in his early development when small turbines operated at speeds as high as 18,000 rpm and when machines had to go through one or more critical speeds. This type of bearing comprised an inner bronze bearing shell which was held from revolving, and was surrounded by three tubes about $^1/_8$-in. thick. There was a definite clearance between the tubes and between the tubes and shell, into which lubricating oil was admitted. The oil acted as a damper which, while it permitted the journal to take an eccentric path, at the same time restrained the eccentricity. The construction was effective, since a well-balanced rotor would go through critical speeds with the critical speed being hardly observable. By 1904 this refinement was found unnecessary and babbitt-lined cast-iron shells were adopted.

At the outset the Westinghouse Company provided radial adjustment for bearing shells. This was accomplished by four keys set in the outside of the bearing shell with liners beneath them. Adjustment of the liners gave radial adjustment to the bearing. This permitted an operation known as "taking clearances." The rotor would be displaced both vertically and horizontally until "touches" occurred, as was noted by revolving the rotor by hand. This operation was carried out with the machine both hot and cold, from which the best radial position of the bearings was determined.

GLANDS AND PACKING

One of the turbine details that was considered unsatisfactory during the early stages of development was the gland or the packings intended to prevent leakage where the rotor shaft passes the walls of the turbine casing. In 1896 the Westinghouse Company, at the inception of its work, followed the Parsons practice of constructing labyrinths of the general form of the dummies of that day. Collars were provided on the shaft and strips were placed on the stator which engaged together and were adjusted to provide an axial clearance as small as practicable. The stationary parts of some of them were made of lead which was cast around the shaft, the shaft being provided with a series of V-shaped grooves.

In all cases means were provided in the labyrinth for admitting sealing steam, in the case of condensing machines, which also served as a leak-off in the case of noncondensing or back-pressure machines.

An objection to this type of gland was that sealing could not be made effective in the case of condensing machines without a considerable amount of leakage to the atmosphere. This may not have been of consequence so far as thermal loss was concerned, but it was a nuisance.

Experiments were carried out with various proposals involving rubbing surfaces, one of which was adopted for a brief period. It comprised a series of bronze spring rings, like ordinary piston rings. The rings were set in grooves in a sleeve which was carried on the shaft, the rings pressing outwardly against the bore of a stationary bushing. A sealing or leak-off connection was provided as before. This construction was effective when new but wore rapidly. The best-fitting ring would do all the packing and would sustain most of the pressure drop; this ring would wear out and the next best-fitting ring would take up the duty, and so on. Parsons, however, successfully employed this construction for many years thereafter, but in cases of turbines of low rotative speed direct-connected to marine propellers.

In 1900 it was thought that a water seal could be made effective. This was tried and immediately adopted. It comprised a runner, which was pressed on the shaft, with radial vanes on either side, like the runner of a double-suction centrifugal pump. The runner operated in a cell and the water was supplied at the periphery For example, the gland of a condensing machine must "pack" against an atmosphere of 15 lb per sq in. The runner might be designed to raise water to a head of 30 lb per sq in. when completely immersed. Water might be admitted at the periphery at 5 lb per sq in. gage (20 lb per sq in. abs). When in operation, the vacuum side of the runner would be full of water for 60 per cent of its radial depth and on the atmosphere side for 14 per cent. A perfect seal was thus obtained, except for what air might transpire through the water.

All three of the foregoing types of glands were installed, as they were developed, in the Air Brake Company's machines. The waterseal gland was regarded as a great advance; it was simple and had no rubbing parts. It was immediately adopted as standard practice and is employed today by several of the turbine manufacturers in nearly its original form.

The simple runner was, of course, ineffective when the turbine was at rest, and it was found that if the air pump was started before the turbine, the inrush of air during the warming period would cause temporary distortion of the rotor. The practice of bringing the turbine to nearly normal speed without vacuum was then adopted. For this reason an embryonic labyrinth was then provided on either side of the runner which reduced water leakage when the turbine was revolving slowly. It has since been general practice, when putting a turbine in operation, to revolve the turbine at low speed before starting the air pump. This requirement is not necessary in the case of a steam-sealed labyrinth.

The mechanical losses incidental to the water gland raised the temperature of the water until there was evaporation at the vacuum side of the runner, and the steam thus evaporated flowed into the turbine. This resulted in sealing of the gland parts when ordinary water was employed for sealing. The obvious and simple remedy was to employ condensate for this purpose.

SOME TURBINES BUILT BETWEEN 1904 AND 1907

An important contract was carried out in 1904 and 1905 for the Pennsylvania, New York, and Long Island Railroad, incorporating three 5500-kw turbine generating sets to be installed in a power station at Long Island City, for operating the electric trains on Long Island and the locomotives in the Pennsylvania tunnels. These were single-cylinder machines and operated at the slow speed of 750 rpm. Early difficulties were experienced because the boilers were provided with disproportionate amounts of superheating surface. Furthermore, the auxiliaries were driven by reciprocating steam engines, the steam for which was taken from the saturated-steam drums, as also was the steam for some pumping operations at the circulating-water intake. During the early operation of the plant, when the load was light, only a fraction of the steam generated passed through the superheaters, which resulted in exceedingly high superheat to the turbines, which was destructive to stators constructed of cast iron. At that time the phenomenon of growth of cast iron was comparatively unknown. Temporary operation was attained by injecting feedwater into the steam line until such time as the superheaters could be changed.

Between 1904 and 1907 fourteen turbines of this design were installed in other well-known power stations, including the 74th St. station of the Interboro Rapid Transit Company, the Waterside station of the New York Edison Company, the Kent Avenue station of the Transit Development Company of Brooklyn, the Gold Street station of the Brooklyn Edison Company, the Delaware Avenue station of the Philadelphia Rapid Transit Company, and the Los Angeles Edison Company. They had ratings of from 5500 to 7500 kw. Some of them have been operating on peak loads until quite recently. The Interboro machine at the 74th Street station still operates on occasions.

A representative test of one of these turbines, supplied to the No. 2 Waterside station of the New York Edison Company and made in 1907, gave a steam rate of 15.16 lb per kwhr at an output of 9830.48 kw with a steam pressure of 177.5 lb per sq in., a superheat of 95.74 F, and a vacuum of 27.31 in Hg. This corresponds to an engine efficiency of 67.6 per cent, including generator losses.

All these machines had cast-iron cylinders of large dimensions, and hence were subject to considerable growth when operated with superheat much in excess of 100 F or a total temperature of 500 F.

DEVELOPMENTS FROM 1904 TO 1909

Later a line of reaction turbines was developed by the Westinghouse Company having capacities and speeds of 500, 750 to 1000, and 1500 to 3000 kw, with speeds of 3600, 1800, and 1200 and 1500 rpm, respectively.

In general the design, an example of which is shown in Fig. 6, did not differ from the 750-rpm machines just mentioned. The reaction blading was arranged for single flow on three diameters in the customary fashion. Speed regulation was accomplished by a flyball governor actuating a steam relay which also caused by-passing of certain of the high-pressure turbine elements for outputs greater than that of the point of best efficiency. Cylinders and steam chests were of cast iron. More than four hundred of these turbines were put in service between 1904 and 1909, and many more during later years.

Rotative speeds were low, so leakage ratios were high in the high-pressure portion. Velocity ratios did not exceed 0.60 because of mechanical considerations. Notwithstanding, this performance was believed superior to that of any competing prime mover. In general practice steam temperatures were comparatively low, so there were few difficulties from high temperature.

THRUST BEARINGS

These machines were equipped with the old-fashioned collar type of thrust bearing. The part carrying the stationary collars was horizontally split, and each half was sensible of axial adjustment. Thus the axial position of the rotor could be controlled as well as the working clearances within the thrust bearing itself. This type of thrust bearing was incapable of sustaining loads much in excess of 50 lb per sq in., so it was essential that the turbine had no material end thrust. The mean diameters of dummies or balance pistons were made equal to the mean diameters of the corresponding blading; but notwithstanding, machines frequently exhibited considerable end thrust when they came to be tested because of differences in pressure drops over the moving and stationary blades. This end thrust was substantially eliminated by carrying out an operation known as "gaging," in which the relative blade openings were changed, by means of twisting tools, until the machine operated under any load, condensing or noncondensing, with practically no end thrust.

This was no problem with the earliest Parsons turbines of 1884 because they were double flow. The introduction of the dummy by Parsons in 1889 constituted a true invention. It enabled blade areas to be doubled, thus reducing the leakage, and the length of the blade path to be nearly half of what it was formerly.

The pivoted segmental type of thrust bearing which is capable of sustaining enormous loads was simultaneously invented about 1910 by Albert Kingsbury in the United States and by Michell in England. Both the Parsons and the Westinghouse companies recognized the value of the invention and thought they saw the possibility of constructing turbines with considerable inherent end thrust, and that dummies could be reduced in diameter and leakage thereby reduced. Both companies got into some trouble. They found that in addition to temperature effects there was more elasticity in the supporting parts than was expected. The axial dummy clearance would change with load.

The Parsons Company, however, overcame the difficulty by reverting to the older dummy practice, that is, constructing a turbine without inherent end thrust. On the other hand, the Westinghouse Company changed the dummy-strip construction from one in which labyrinth clearance was axial to one in which it was radial. This radial labyrinth was more subject to leakage than one with a closely adjusted side clearance, but close axial adjustment was not required.

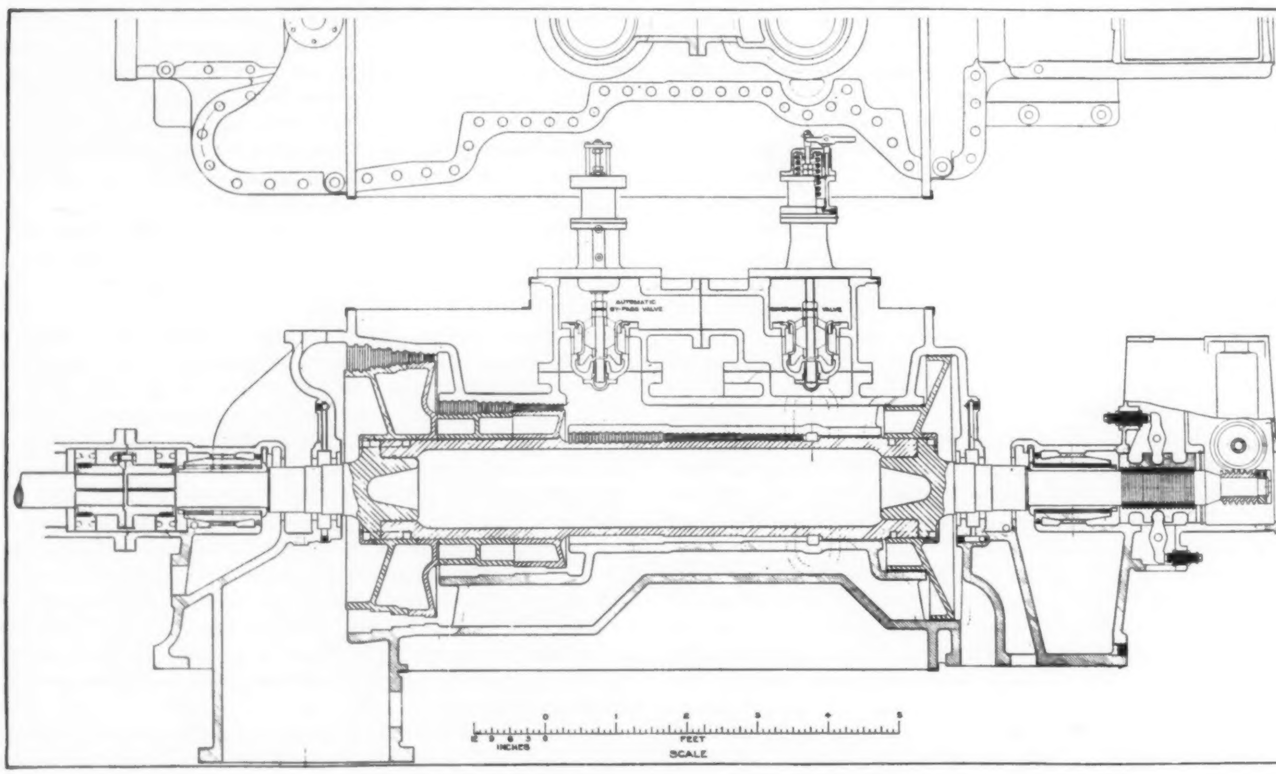


FIG. 6 STANDARD REACTION TURBINE, 1907 TO 1909

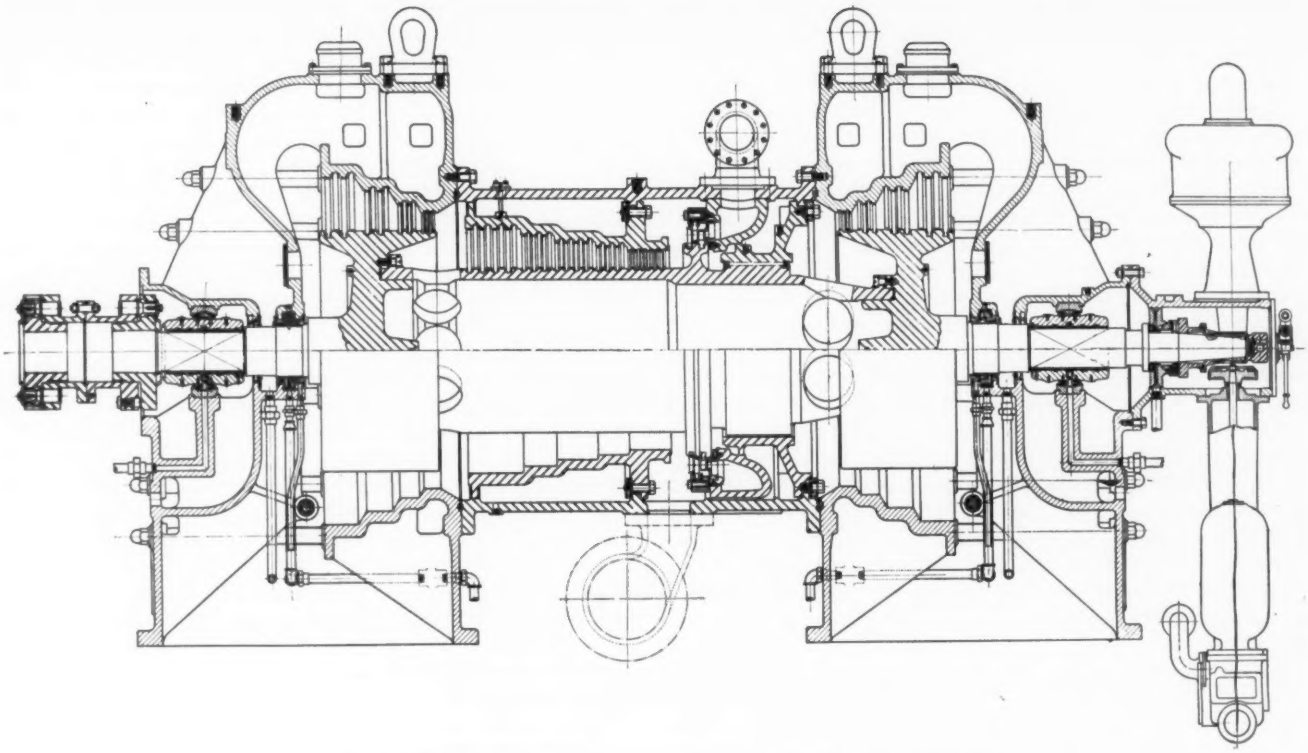


FIG. 7 SINGLE-DOUBLE FLOW TURBINE OF 1912, 20,000 KW, 1800 RPM

TURBINE ROTORS

The earlier turbine rotors comprised a forged shaft or body having a diameter appropriate for the high-pressure group of reaction blades. The two lower-pressure groups of reaction blades were carried on cast-steel rings which were pressed on to the shaft. The shaft was bored in order to reduce weight and deflection. Spindle ends of higher-carbon steel were pressed into the shaft body. The ends formed the journals and carried the coupling, gland, and thrust-bearing parts. The press fit was relied upon for rigidity and to transmit the torque between the body and the spindle ends. In one or two cases both here and abroad of machines operating at high temperature, the spindle end at the high-pressure end of the turbine became loose due to differences of temperature. This was readily remedied by providing channels to admit high-pressure steam to the axis of the spindle end within the press fit.

Later, spindle ends were provided with a slotted flange and a shorter press fit. They were secured to the body by shrink links, as shown by Fig. 6. More holding area could be obtained by these means than by bolts.

The rotor of the Hartford turbine of 1900, except for the spindle ends, comprised cast-steel sections bolted together. Later cast-steel rotor parts came to be extensively employed for several years, particularly for the larger machines. In the case of machines of the type shown in Fig. 7 the large-diameter part carrying the low-pressure blades and the spindle end were cast integrally. Cast steel was found eminently satisfactory for these purposes. Sound castings without blemish could be obtained, providing proper consideration was paid to risers and to the isothermals during cooling.

Cast steel is of granolithic structure and hence cannot have the physical characteristics of a sound forging. This, however, was not of great moment in the early days when generators did not operate at such speeds as those of today. Occasionally, forgings were offered at competitive prices, generally from abroad. These were not regarded as satisfactory as castings; most of the few purchased were rejected because of piping and other physical defects. Obviously, the need for employing higher stresses has brought about development in the steel-forging industry and such conditions as described have not existed for several years.

SOME DESIGN CHANGES INITIATED BY MR. WESTINGHOUSE ABOUT 1907

Many changes in design were initiated about 1907 that were largely instigated by Mr. Westinghouse.

(1) Electric generators for the standard synchronous speeds began to be designed for greater capacities, rendering them more adaptable to the speeds appropriate for the steam turbine, or, in other words, greater capacities at the standard synchronous speeds. Progress in this respect has been continuous. This is, directly and indirectly, the most important factor that has brought about improvement in power-station economics.

(2) The early steam expansion in an all-reaction turbine took place over a long small-diameter portion of the turbine. This portion occupied about three quarters of the length of the steam path and did but 20 or 25 per cent of the total work. In this portion leakage ratios were high because of the small steam volume and hence small blades. Therefore a moderately high-speed, two-row, impulse element was substituted for the small-diameter reaction elements, in which some 20 per cent of the total work would be carried out. While the inherent efficiency of the impulse element is lower, it is without leakage. It also effects a shortening of the whole turbine. By this time steam temperatures had begun to increase, so advantage was taken of arranging the nozzle and nozzle chambers as a separate member of the turbine casing. Thus the turbine casing was not exposed to high pressure and temperature.

(3) Machines of the greater ranges of capacity came to have their low-pressure blade portions arranged for double flow,

which permitted ample low-pressure blade areas to be obtained with conservative blade speeds and stresses. At that time a mean blade speed of 400 ft per sec was not usually exceeded.

Some of these machines were constructed entirely for double flow, except for the impulse element. Most of them, however, were constructed for "single-double-flow;" that is, the impulse element was followed by a single-flow series of reaction elements and the steam was then divided and passed in parallel through two series of reaction elements which were located at each end of the machine. The intermediate reaction elements were end-balanced by means of a dummy which had to be located between the impulse element and one of the series of low-pressure blading. It was, therefore, somewhat remote from the thrust bearing. Differing expansions due to temperature rendered it difficult to maintain this dummy in axial adjustment, and some difficulties were encountered until the axial form of labyrinth was changed to one of radial form.

During 1909 a number of the foregoing types of machines were shipped, their capacities ranging from 6000 to 10,000 kw at 750 to 1800 rpm. The type was later extended at 3600 rpm to 4500 kw, and by 1912 up to 20,000 kw at 1500 rpm. In some instances this general principle of design continued to be employed until about 1924, with capacities up to 35,000 kw at 1500 and 1800 rpm. A typical section of this type is shown in Fig. 7.

DEVELOPMENTS IN STEAM ADMISSION

When an impulse element was first introduced for the first range of expansion it was soon found that the puff system of steam admission, which had always been employed with reaction turbines, was inimical to efficiency. With an all-reaction turbine the efficiency was about the same whether the steam admission was steady or intermittent; if anything, the efficiency was slightly better when steam was admitted in puffs.

These experiences resulted in substituting for the steam relay a hydraulic servomotor, operated with oil. The oscillation of the governor mechanism, which is incidental to the puff system of admission, was still highly regarded as a splendid means of obtaining close and stable speed regulation. Therefore, the governor linkage combined with the hydraulic relay was similarly oscillated, but the relay was provided with lap so that the inlet and outlet relay ports were slightly uncovered at each oscillation. By these means the regulating valves themselves oscillated only about $^1/_{32}$ in. and steam admission was thus rendered substantially constant, but the advantage of oscillating the governor mechanism was retained.

BLADES AND BLADE FASTENINGS

By 1915 improvements in blade fastenings and their materials permitted the employment of higher blade speeds, up to 550 and 600 ft per sec mean speed, so that the low-pressure elements of fairly large machines could easily be arranged for single flow. Completely single-flow machines were devised in which the first range of expansion was carried out as before by means of a two-row impulse element with grouped nozzles. The groups came in and out of action in response to the speed-responsive governor as the load varied. The capacities of these machines first ranged from 500 to 3000 kw at 3600 rpm, and up to 12,500 kw at 1500 and 1800 rpm. By 1925 further development of the generator permitted 6000-kw machines operating at 3600 rpm to be constructed. The smaller ones were arranged as three-bearing sets with the turbine and generator rigidly coupled.

There has always been a striving to increase blade speeds; in other words to obtain the greatest possible area of last blade-row annulus with a given rotative speed. The cost of steam turbines is largely influenced by the speed at which they are designed to operate. The higher the speed, the lower the cost, so long as undue cost is not incurred because of complexities of design to avoid undue stress. The area of the annulus occupied by the last row of blades is an important factor. It may be taken as a measure of the true capacity of a turbine designed to expand to a given exhaust pressure. This area is limited by the diameter of the drum or disk because of stress and the ratio of blade height to drum or disk diameter. If high efficiency is desired, the latter is limited because of the disparity in blade speed between the root and the tip of the blade. When these limits are reached, greater last-row annulus area and hence greater capacity can be obtained only by reducing the rotative speed, which increases cost per unit of capacity in some proportion inversely as the speed. Consider two geometrically similar turbines, the one having twice the linear dimensions of the other. The area, and hence the capacity, would be four times as great, but the weight, varying as the cube of the linear dimensions, would be eight times as great. This, while true, is academic, because, under such circumstances, geometric similarity would not be wholly practiced.

Increased area of last-row annulus for a given speed may be obtained by other means than reducing speed. For example, by providing two or more flows for the last expansions, as has been already indicated. Another means, proposed by Baumann of England, about 1918, and known as "multiple-exhaust blading," gives twice the exit area for a given blade dimension. The steam path of the two penultimate rows was divided into an inner and an outer tier. From the outer tiers of these the steam discharged directly to the exhaust. The steam passed the inner tiers with as little positive or negative work as possible. This construction was adopted for a time by the Westinghouse Company but was abandoned because of a belief that a higher leaving loss was a lesser penalty than the losses incidental to the steam's passing the inner tiers. Furthermore, the construction proved costly.

The higher the last-blade velocity, the greater the axial leaving velocity with any given velocity ratio and blade angle. Therefore, leaving losses may be reduced by operating the last blade rows at some comparatively low speed. A striking example of accomplishing this was the 50,000-kw turbine supplied in about 1922 by C. A. Parsons and Company to the Crawford Avenue station of the Commonwealth Edison Co., where the last expansion, from about 26 in. of vacuum to exhaust pressure, was carried out in a large-diameter turbine with long blades, operating at 720 rpm. Since blade speed profoundly affects cost, Sir Charles Parsons has said that the design he adopted for the Commonwealth machine was not likely to be repeated. The advantages of this construction may be obtained, at least in part, by means of the cross-compound principle, which will be referred to later. This had been introduced by the Westinghouse Company some seven years earlier.

Blade speeds have continuously increased, until now 1250 ft per sec tip speed has been attained. With these higher blade speeds, erosion or a wearing away of the last rows of blades has been encountered when moisture is present. It is believed that the slowly moving particles of moisture create a high localized stress. This has been ameliorated by shielding the backs of the inlet edges with high-strength material. Means also have been adopted for abstracting moisture as it is precipitated during expansion, with at least partial success.

THE CROSS-COMPOUND TURBINE

In 1914 three 30,000 kw turbines were supplied to the 74th Street station of the Interboro Rapid Transit Company of New York. The contract was regarded as an important one, inasmuch as the turbines had a greater capacity than any thus

far built, and gave opportunity for a new era in efficiency. The company adopted the policy of employing conservative design, to the end that increased reliability might be coupled with the greater capacity and improved efficiency, which usually had not been obtained in such instances. With this in view, the Westinghouse Company introduced the cross-compound principle. In this instance a single-flow high-pressure turbine element drove one generator at 1500 rpm and a low-pressure turbine element drove another at 750 rpm. The low-pressure turbine was arranged for double flow. The two generators were electrically solid-coupled. The turbines contained reaction blading exclusively. The operating results justified the design inasmuch as a new record was set in efficiency and the machines are believed to have a higher reliability factor than any others. They are still in operation and in good condition. They would be too ponderous and costly for a modern market.

A valuable feature of the cross-compound principle lies in the fact that the turbine elements driving separate generators may be arranged to operate at different speeds, synchronous speeds being selected which are most appropriate for the steam volumes that obtain in the respective ranges of expansion. Furthermore, since each of the elements is self-contained and carries out a fraction of the total expansion, the design of the individual element becomes simpler and more conducive to reliability.

In one form or another these general principles were repeated a number of times in capacities up to 160,000 kw, but purchasers seemed to prefer combinations that drove a single generator. If the turbine elements should be desirably compounded, they preferred that they be tandem-coupled, although there has not been a single instance of difficulty because two generators were separately driven by separate elements of the same turbine. Perhaps this was because European builders had more fully practiced the tandem-coupled construction for their larger machines, or perhaps American purchasers merely fancied a larger name plate on the generator.

Following 1917 a number of tandem-compounded machines were sold in what was actually a reversion to the designs of 1901 to 1904, but in capacities of from 30,000 to 50,000 kw, at 1200 and 1500 rpm. Later the tendency of design was to construct large power machines up to 75,000 kw in a single cylinder.

INCREASING THE STEAM PRESSURE AND TEMPERATURE

The first material increase in steam pressure in this country was adopted by the Commonwealth Co. in about 1923, when 600 lb per sq in. at a temperature of 725 F was selected, which then was regarded as a maximum safe temperature. In order to avoid excessive moisture at the end of the expansion, steam reheaters were provided in certain of the boilers. Reheating soon lost favor. It was regarded as a nuisance because of the two cumbersome pipes going between the boiler and engine rooms, and also because of the necessity of providing the reheated-steam inlet to the turbine with some special speed-control apparatus for the purpose of preventing overspeeding of the turbine on loss of load, from the steam enclosed within the reheater and piping. These are reasons why there has been the striving for higher and higher operating temperatures. Could a turbine be operated with an initial steam temperature of 1000 F, advantage might be taken of a pressure as high as 1200 lb per sq in. when, without reheating, exhaust moisture would approximate $11^1/_2$ per cent without consideration of what moisture might be withdrawn from the turbine during expansion.

Should "once-through" boilers come into use, operating at pressures of 2000 lb per sq in. or more, there would be a reversion to reheating, but the reheating would be carried out at some pressure of the order of 600 or 800 lb per sq in. when the objection to large connecting piping would disappear.

SPEED-REDUCTION GEARING

The Melville-Macalpine speed-reducing gear was proposed in 1906 as a means to progress in ship propulsion and was promptly taken up by Mr. Westinghouse. The feature of this gear was the carrying of the pinion bearings in a flexibly mounted frame, by means of which alignment was maintained between the gear and pinion regardless of movement of the foundation. To a partial degree it also compensated for torsional deflection of the pinion. The financial crisis of 1907 prevented a practical demonstration until 1909. These gears permitted the construction of more satisfactory turbine-driven direct-current generating sets. Their principal application was, however, to ship propulsion. Up to that time turbines were direct connected to the propeller shafts, when, because of the disparity of appropriate speed between the turbine and the propeller, they were applicable only to high-powered fast ships. They were not properly applicable to cargo ships and the like, which constituted some 90 per cent of the ships afloat. The reduction-gear development made turbines applicable to all ships, although there may be differences of opinion concerning the application of internal-combustion engines in some cases of low powers.

Two 3750-kw 1800-rpm noncondensing turbines geared to 180 rpm direct-current generating sets were installed in a plant of the Cleveland Electric Illuminating Company in 1912. The exhaust from these was used for heating.

The first marine geared installation was the U. S. Collier *Neptune* in 1914.

LOW-PRESSURE TURBINES

Early steam-turbine history discloses other activities besides that relating to complete-expansion turbines. One of these has been the application of low-pressure turbines to existing reciprocating-engine plants when the turbine could usefully expand the steam to limits of low exhaust pressure, of which the reciprocator was incapable. This business began in 1908, but by 1912 the market for land application was nearly satisfied, and not many more applications remained in the country. This is aside from modern large-capacity turbines which are compounded, in which the last ranges of expansion are carried out in a separate low-pressure turbine casing.

No small degree of ingenuity was displayed in the application of low-pressure turbines. Obviously, when both the generators could be operated in parallel, the turbine developed all the energy it could with the steam it received, and the receiver pressure between the reciprocator and turbine varied with the load. Speed regulation, except for an emergency governor on the turbine, was accomplished by the engine governor.

There were instances where the engine and turbine operated on independent loads, when the turbine governor by-passed some proportion of the engine exhaust directly to the condenser. The turbine governor built up the engine exhaust pressure to that required for the turbine to carry its load.

There were also instances of low-pressure-turbine application to engine-driven mills. Both the engine and the turbine set were connected to the mill shafting; the latter by means of a synchronous motor. Generally, the turbine also carried an electrical load that was extraneous to the mill. Speed regulation was accomplished solely by the engine governor. For instance, if the external electrical load increased, less energy would go to the mill from the synchronous motor, and more from the engine. With an extreme unbalance of low mill load and high electrical load, part of the energy for the electrical

load would come from the mill shafting via the synchronous motor. By these means not only was there an increase in capacity and a reduction in fuel consumption, but also a perfect proportioning of load between the mill and external electrical load, regardless of load variations taking place independently in each of the two power requirements.

In a few cases low-pressure turbines operated with the exhaust from intermittently operating engines, such as rolling-mill engines. In these cases a heat accumulator, such as that devised by Rateau, was interposed between the engine and the turbine. This method was not practiced in the United States to the extent that it was in Europe. An extreme example of this kind of installation, which, however, is not in conjunction with intermittently operating engines, is at the Charlottenburg plant of the Berlin Electricity Works, where a bank of 16 great accumulators supplies the steam for the daily peaks. The accumulators are charged by the boilers during times of base-load operation. It is believed that such an installation cannot be justified when fixed charges are considered.

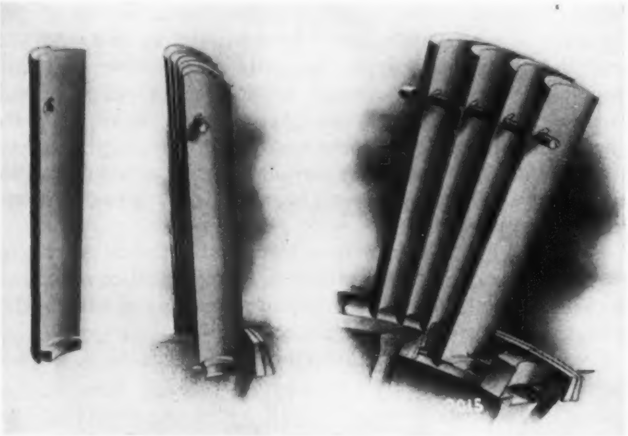


FIG. 8 FORM OF REACTION BLADING ADOPTED IN 1912

Naturally most low-pressure turbines were arranged to take high-pressure steam automatically when there was a deficiency of exhaust steam. Many of them contained a high-pressure turbine element which came into action at such times of deficiency. These turbines became known as "mixed-pressure" turbines.

The application of low-pressure turbines was a means of rehabilitating existing plants. It has its counterpart today, but at the opposite end of the expansion range, by the installation of extra high-pressure-turbine generating units which exhaust into the steam line which had supplied steam to the existing turbines.

EXTRACTION TURBINES

Another activity began in 1911 when the Westinghouse Company visualized a market for extraction-type turbines which would bleed out partially expanded steam at any desired pressure for industrial-process heating or for any other kind of heating up to the saturation temperature of the available steam. It recognized that an industrial power plant should not be able to justify installing a steam power plant solely for the purpose of furnishing power if power lines from a utility company's central station are available. The central station should be able to supply power for less price than the cost from comparatively small industrial plants; but if the industrialist requires steam for some heating process, the complexion changes entirely. Steam may be generated at some high pressure and expanded to some desired lower heating pressure with little loss in its value for heating purposes and so develop for low cost what is called "by-product" power. With a thermodynamic accounting, the energy generated by the turbine from the partially expanded steam which is employed subsequently for heating purposes is at a thermal efficiency of the order of 90 per cent, while the best the central station can do is to generate energy at a thermal efficiency of some 34 per cent.

In 1911 while designs for these types of turbines were in embryo, some fourteen were sold having ratings of 500 to 1500 kw.

The earliest machines were provided with automatic means for maintaining constant pressure in a heating system, provided the available load was sufficient, with all the steam being extracted. The extraction-turbine business is still important.

DEVELOPMENTS AFFECTING STEAM-TURBINE PROGRESS

This review of early steam-turbine history up to about 20 years ago would not be complete without special reference to blading and its materials. However, at this point it is pertinent to remark that the tremendous improvements in efficiencies since the inception of turbine activity in this country have been more the result of things extraneous to the turbine, than to development of the turbine itself. There have been important developments in metallurgy and in the design of turbine details which have rendered the turbine more reliable and capable of operating under the more exacting modern operating conditions, particularly that of temperature. Factors that have contributed to improvements in efficiencies are:

(1) Electric-generator development has increased capacities many fold at a given rotative speed. It has permitted optimum design constants to be employed in the design of the steam path.

(2) The introduction of the regenerative cycle, in which steam is extracted into a successive series of feedwater heaters. By this means by-product power is obtained.

(3) Condenser developments giving lower exhaust pressures. These have increased inherent turbine costs.

(4) Boiler developments giving ever higher temperatures of superheated steam, which did not minimize turbine operating difficulties.

(5) Boiler developments giving higher steam pressures.

(6) Improved methods of arranging and operating the essential auxiliary machinery at the hands of central-station engineers.

TURBINE BLADING

The reaction-blade construction employed in the earliest turbines has been adequately described in the foregoing. In 1912 the form of reaction blading shown in Fig. 8 was adopted. This was regarded as a great improvement inasmuch as no calking was required. The more highly stressed blades were made from drop forgings with integral roots forged thereon which fitted into dovetailed grooves. This construction had been employed for the low-pressure blades in the case of the Hartford turbine in 1900.

The dovetail form of fastening to the surface of a drum proved faulty in later years when extremes of temperature came to be employed. Blades must be expected to heat and cool at a greater rate than the structure which holds them. The quicker heating would slightly crush the roots and then, with the quicker cooling, they would become slightly loose. Repeated heating and cooling would cause the blades to progressively rise in their grooves. This brought about the adoption of rectangular abutments as the holding means. Objection to dovetails may not hold in the case of blades attached to disks if a proper degree of elasticity can be given to the walls of the groove.

Corrosion or erosion of cast-iron cylinder walls was not unusual in early days. This led to the development about 1908 of a bronze liner for a worn cylinder. The cylinder was rebored, the blade grooves modified, and blades inserted with one leg of angle-shaped bronze strips cut in lengths of a few inches in the same groove, the other leg of the angle thus forming a new cylinder wall. Many machines have been so treated. By its means original blade clearances were restored, resulting in the machine's having a longer life of original efficiency, not only because a comparatively noncorrosive cylinder wall was provided, but because further distortion of the cylinder structure was less likely to occur. Of course, bronze linings would not serve with modern temperature conditions but one of the forms of stainless steel could be used.

Internal corrosion of turbines has, to a large extent, disappeared because of exclusion of oxygen from the feedwater by means of deaeration processes.

As already stated, the earliest blading material was made of delta metal. At the recommendation of a supplier a change was made to a phosphor bronze, containing about 97 per cent copper and 3 per cent tin.

Considerable blade breakage was experienced, occasionally because of contact between the stationary and rotating elements, but more frequently because of fatigue resulting from blade vibration, which was thought to be due to the low fatigue resistance of these bronze alloys. The employment of carbon steel was considered, but it was feared that corrosion would preclude its use. Carbon steel was first tried experimentally in one or two turbines with surprisingly satisfactory results in respect to corrosion. Its more extended use, however, showed severe corrosion in too many cases for it to be regarded as a satisfactory material. Notwithstanding, several machines bladed with carbon steel operated for many years without any particular corrosion. As late as about 1923 the 50,000-kw turbine supplied by C. A. Parsons and Company to the Commonwealth Edison Company was bladed with carbon steel, with which it is believed to be still operating.

The corrosion experienced occurred principally at the dew-point of the steam. Many researches and chemical analyses of samples of feedwater and steam were made. Outside chemists were retained, but no definite explanation resulted. The corrosion seemed obviously the result of some corrosive element in the steam. This was further evident because corrosion was serious in some plants and negligible in others. Doubtlessly, corrosion was principally the result of oxygen in the feedwater, although other theories were evolved, such as leakage of salt circulating water into the condensate, which, when heated with soda-ash, formed hydrochloric acid.

In about 1902 attention was called to a copper-clad steel. It was produced in ingots about 3 in. in diameter, the cross section of which comprised 25 per cent copper. The ingots could be rolled down to any degree of fineness and the percentage of copper would remain unchanged. This material seemed promising for turbine blading. It was expected that it would have the strength and fatigue resistance of steel combined with the noncorrodibility of copper. It was employed to a considerable extent, but it was found that if the copper coating became punctured the corrosion of the steel was as bad as ever.

The result of a blade strip or severe rubbing never caused damage beyond that to the blades themselves as long as the weak copper alloys were employed, but such happenings with the stronger ferrous materials would sometimes cause such local heating of the rotor that it would become internally stressed and distorted. A method of repair was adopted that was in part the result of experience in the manufacture of projectiles. The turbine rotor would be dismantled and the damaged parts well slushed with cylinder oil and buried in sand within a container. The whole was placed in a furnace, annealed, and allowed to cool in the furnace. On removal, the rotor part would be found free from oxidation, the original polish undiminished. The part would then be remachined and be without internal stress and the rotor effectively rehabilitated, except for trifling modifications of blade length.

Experience with copper-clad blading led to an anticipation of a principle, later proposed by Parsons, known as "thin-tipping." In the case of the copper-clad blades it merely consisted in eating out the steel at the tip of the blade with acid, leaving a thin copper shell of blade form. This thin copper shell could cause no particular injury in case of a rub, but it was, however, fragile and sometimes did not survive the installation of the blading.

The foregoing difficulties with steel and copper-clad reaction blades resulted in a reversion to the use of phosphor bronze in 1909.

At this time impulse blades came to be employed, which were entirely different in form from reaction blades. Cast manganese bronze was employed in experimental machines, but in regular practice blades were made from an extremely low-carbon forged iron which was satisfactory from the standpoint of corrosion, but had low fatigue resistance because of slag inclusions. It frequently resembled old-fashioned fagoted iron.

In 1912 attention was called to a low-carbon electric-furnace steel, manufactured at the Paul Girod Works, at Ugina, France, containing 0.07 to 0.08 per cent carbon and 4.75 to 5.25 per cent nickel. Following investigation, this material came to be employed for impulse blades and later for the higher stressed reaction blades. The average physical characteristics of the Girod steel in the heat-treated condition was as follows:

Ultimate strength, lb per sq in.	90,000
Proportional limit, lb per sq in.	50,000
Elongation, per cent	25
Reduction of area, per cent	60

The elastic limit fell off about 15 per cent at 500 F.

From the standpoint of corrosion it was far more satisfactory than any ferrous material that had been employed before, but not as satisfactory when in the dew-point of the steam as phosphor bronze or the stainless steel that came to be later employed. Low-carbon nickel steel is, however, as little subject to corrosion as any other material in the superheated-steam range and therefore is still there employed, although it does not possess the strength characteristics of the modern stainless steels. The lower stressed reaction blades continued to be made of phosphor bronze.

The War interrupted the supply of this material from France, and an American supplier had to be found. The material presented a new art in the manufacture of steel in the United States. Following a few difficulties, a supplier was obtained in 1914.

In 1913 attention was called to pure nickel, produced by a process devised by Dr. Hennig. It contained plus 99 per cent nickel; its physical characteristics ran as follows:

Ultimate strength, lb per sq in.	75,000
Proportional limit, lb per sq in.	35,000
Elastic limit, per cent	20
Reduction of area, per cent	55

Its strength fell off about 10 per cent at 700 F. It was eminently noncorrosive and lent itself readily to drawing and forging operations. It was first employed with satisfaction in replacing some impulse blades of the low-carbon iron which had failed. Pure nickel might have been employed at that time for reaction blading, inasmuch as phosphor bronze had never been entirely satisfactory. An objection to its use was the cost.

Some of the difficulties with phosphor bronze were suspected to be due to the low tin content. Certain metallurgists recommended a tin content as high as 5 or 6 per cent. This recommendation was unfortunate because of a hot-short range below the silver-soldering temperature.

In 1920 a manganese-copper material was being employed by Parsons in England. This was investigated and came into general use in 1921 instead of phosphor bronze for reaction blades. It is easily worked and holds up its strength at high temperature better than any other known rich copper alloy. Its physical characteristics in the cold-drawn condition averaged:

Ultimate strength, lb per sq in.	60,000
Yield point, lb per sq in.	48,000
Proportional limit, lb per sq in.	31,000
Elongation, per cent	20
Reduction of area, per cent	70

At a temperature of 700 F the tensile strength fell off about 25 per cent and the elastic limit about 60 per cent.

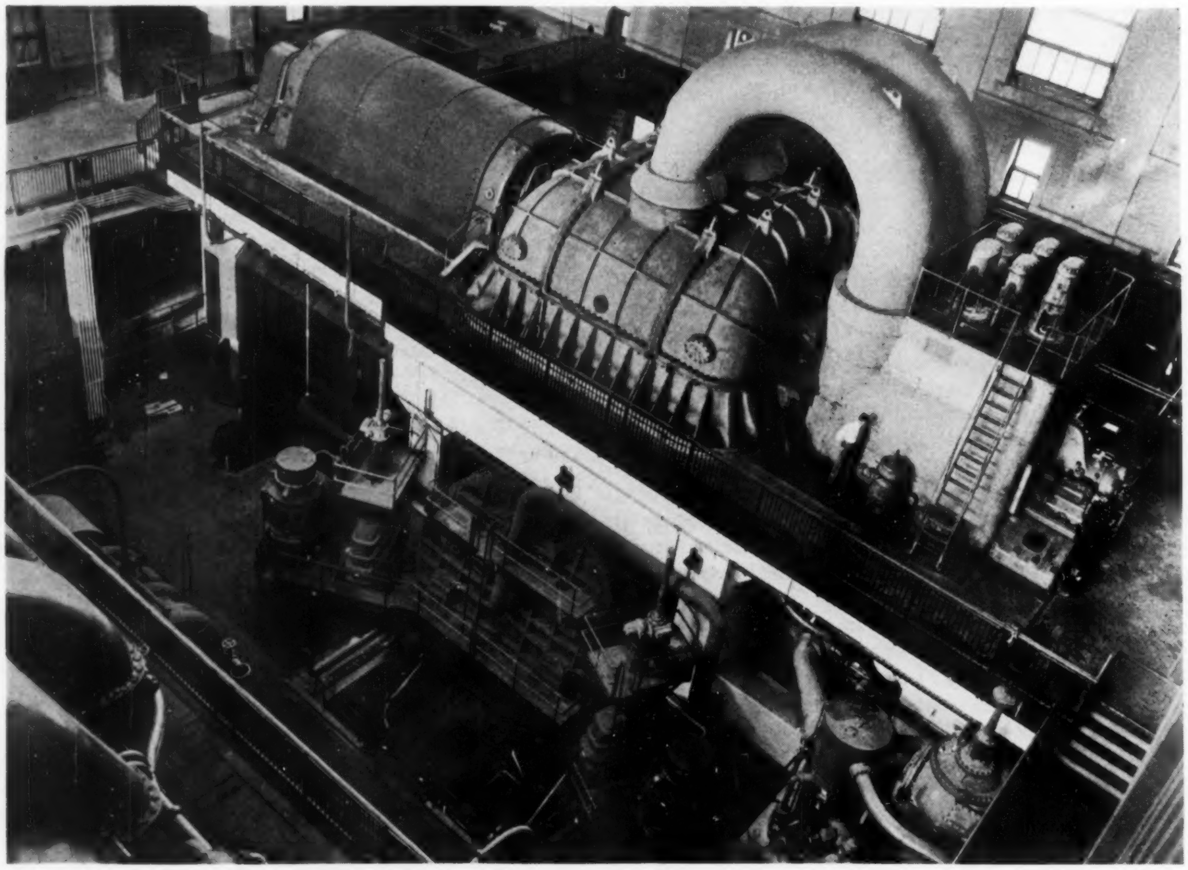
Pure nickel continued to be used occasionally in cases where trouble had existed and higher strength or less weakening with temperature was required. The high fatigue resistance of pure nickel was manifest in a certain marine installation where blades had failed because a high-frequency torsional vibration obtained. It might have had a more extended use in spite of high cost had later suppliers been able to provide material of the quality that was first obtainable.

Throughout the early experiences, say from 1910 to 1920, monel metal was sporadically employed for blading; usually, however, at the insistence of some purchaser. Monel metal was regarded with some suspicion by the Westinghouse Company because it sometimes contained streaks of carbon which affected fatigue resistance. Even with pure nickel intercrystalline weakness was sometimes experienced, which usually was the result of absorption of sulphur because of injudicious furnace treatment during the various rolling operations.

These difficulties, both with monel metal and pure nickel, are now believed to have been the result of manufacturing the ingots in steel rolling mills where furnaces and rolls were regularly employed for ferrous material. It is believed these conditions would not exist today.

By 1921 some forms of so-called "stainless" steels were developed in Europe, principally for cutlery. They were generally high in carbon, 0.30 to 0.50 per cent, and contained various percentages of chromium, and in some cases nickel was also included. All had high strength characteristics and had high resistance to corrosion, at least in the hardened and polished condition. Naturally, such material had appeal for application to turbine blading and many forms of it were investigated. At first they were not regarded favorably, primarily because many of them were not easy to machine, nor did they lend themselves to forging operations. Furthermore, it was found that some of them were subject to intercrystalline penetration of the silver solder. The previous experiences with extremely low-carbon steel resulted in a suggestion by N. L. Mochel that a combination of low-carbon steel and a moderate amount of chromium might have the desired characteristics of high strength, fatigue limit and low creep limits, under temperature, together with noncorrodibility.

The development and use of stainless steel as well as the development of Westinghouse turbines during the last two decades is modern history and is beyond the scope of this review of early Westinghouse steam-turbine exploitation.



MODERN STEAM TURBINE GENERATING SET, 165,000 KW, 1800 RPM

THE PORT WASHINGTON PLANT

Unique Design Features and Operating Experiences

By F. L. DORNBROOK

THE MILWAUKEE ELECTRIC RAILWAY AND LIGHT COMPANY

THE DESIGN of the Port Washington plant is based on the design and operating experiences of the Lakeside plant, except that such improvements are incorporated as were justified by operating experiences and progress in the power-plant art. The principal improvements are the unit design and the use of a temperature of 825 F for both throttle and reheat steam. Lakeside commenced using 1300-lb steam pressure in the fall of 1926, so that the use of this pressure at Port Washington is not new to the company.

In carrying out the idea of unit-design, selections were made calling for an 80,000-kw tandem-compound turbine generator and a single 690,000-lb-per-hr bent-tube type of boiler with a combination radiant and convection superheater and an all-radiant reheater. Only one set of auxiliaries for this particular unit has been provided. The unit design makes possible important investment and operating savings.

At the time of this writing, Sept. 10, 1936, the plant has been in operation almost continuously for $10^1/_2$ months. The outages so far experienced have been for the most part due to load conditions rather than operating difficulties. The boiler and turbine have performed with equally high reliability. In spite of widely fluctuating loads the superheat and reheat temperatures at the turbine have remained unusually uniform to the benefit of both reliability and efficiency. Both long and short operating periods have been experienced, so that a fair test of all operating conditions has been obtained.

TYPE OF INSTALLATION

The high-pressure installation at Lakeside consists of four 1300-lb boilers (300,000 lb per hr each) delivering steam to four 7700-kw superposed high-pressure turbines, which exhaust at constant pressure through reheaters in the boilers and then into the main station header at 300 lb. Constant-back-pressure operation involves important energy losses at partial loads, and it was the desire to eliminate these losses that prompted the decision to install a compound turbine at Port Washington.

Compounding introduced a new problem because turbine characteristics are different for this type of operation. With the Lakeside constant-back-pressure machines the temperature of the steam leaving the turbines rises rapidly with decrease in load. This resulted in the selection of a convection surface for the reheater placed behind the first bank of boiler tubes, and through its use a constant reheater outlet temperature over a wide load range has been obtained. With compounding operation, on the other hand, different reheater characteristics are required to give the uniform outlet temperature that is so essential to efficient turbine performance. Therefore, a radiant surface, whose temperature slope is opposite to that of the convection surface, and with which a great deal of experience had been had at Lakeside, was decided upon for Port Washington.

Contributed by the Power Division for presentation at the Annual Meeting, New York, N. Y., Nov. 30 to Dec. 4, 1936, of The American Society of Mechanical Engineers.

The superheater consists of both radiant and convection surfaces, and the steam from the boiler first passes through the radiant section and then through the convection section before going to the turbine. In this way the metal of the radiant elements on the furnace side walls can be kept at a lower temperature. The combination of radiant and convection surface also automatically maintains a constant outlet temperature over a wide load range.

A cross section of the boiler layout showing the relative positions of the radiant and convection sections of the superheater and the headers for the rear-wall reheater is given in Fig. 1. The boiler has three drums and is set over a low-heat-release hopper-bottom furnace, the latter being cooled with steam and waterwall surfaces on six sides.

The turbine-generator unit is shown in Fig. 2. The turbine, a cross section of which is shown in Fig. 3, operates at 1800 rpm and is supplied at the throttle with steam at a pressure of 1230

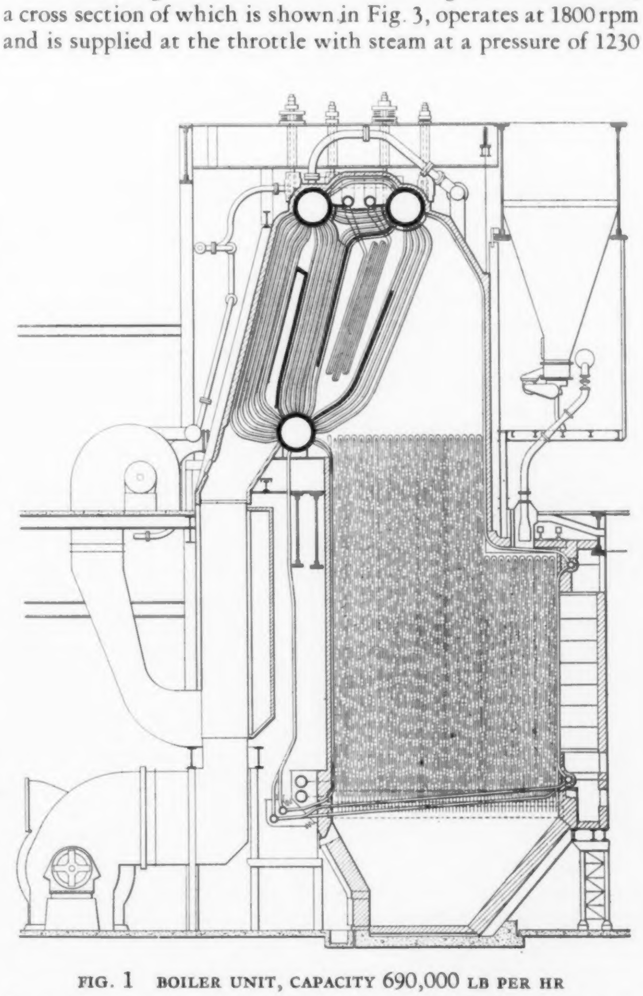


FIG. 1 BOILER UNIT, CAPACITY 690,000 LB PER HR

(The three-drum bent-tube boiler is located over a low-heat-release hopper-bottom furnace, permitting the use of radiant superheating and reheating surfaces on the furnace walls.)

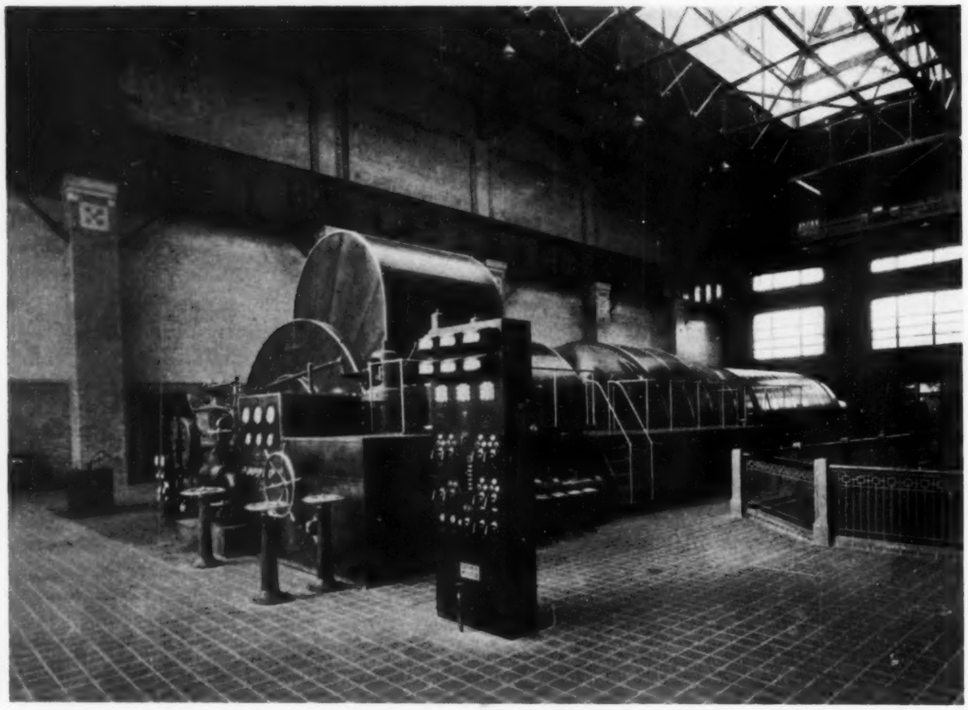


FIG. 2 TURBINE-GENERATOR UNIT, CAPACITY 80,000 KW

(The unit is equipped with three admission valves which permit operating at economic points over a considerable load range.)

lb gage and a temperature of 825 F. Reheated steam, also at 825 F, is readmitted to the turbine part way through the high-pressure section. The reheat pressure varies with load, its maximum being 425 lb at 85,000 kw. The location of the reheat connections part way down the high-pressure casing eliminates troublesome high-temperature shaft seals.

The flow-diagram, Fig. 4, indicates schematically how steam and water flow between the boiler and the turbine through the various pumps and heaters.

STARTING PERIOD

A fire was started in the furnace on September 19, 1935, and kept burning for several days to "boil out" the boiler thoroughly.

The turbine was first cut in on the load on October 14, 1935, when 6000 kw was carried for an hour. The load was taken off when it was found that the governor was not functioning properly. On October 16 the turbine trip pin was bent while checking the overspeed governor and this required replacement before further operation could be attempted. The following day, October 17, a 20,000-kw load was carried for 11 hr, and this might be considered as the day for the initial operation. The CO_2 in the furnace had to be held at 9 per cent in order to limit the reheat temperature to 825 F. The rear-wall reheater had been temporarily covered with a thin layer of insulation so that the desired temperature could be reached gradually and to preclude danger of overheating from unforeseen occurrences. On October 18, eighteen more hours of operation at 22,000 kw were obtained. The unit was taken from service that night and given a casual inspection. It was found that practically all of the insulation on the reheater surface had fallen off. On October 21 the turbine again ran for 12 hr at an average load of 22,000 kw with a peak of 30,000 kw. Some trouble was experienced with unstable combustion when the load was first carried. The operation continued for four days more, each of 24-hour duration, with the load varying between 26,000 and 28,000 kw. CO_2 again had to be limited, this time to 6 per cent to prevent the reheat temperature from exceeding 825 F maximum. On October 25, the operation was such that for the first time there was no foaming of the boiler water. Over the following week end the pulverized-coal burners, which were of the vertical fan-tail type, were changed by reducing the tip area to 50 per cent to throw the flames farther down into the furnace. On October 31, the unit was again started and 7 hours' operation obtained at a load of 46,000 kw, maximum. The CO_2 was being held to 8 per cent to limit the reheat temperature.

A prolonged shut-down was then decided upon to (1) increase the front-wall air-port area, (2) reduce the reheat surface and substitute waterwall surface for it, and (3) complete an appreciable amount of construction work which was necessary to permit continuous operation. Provision had been made in the design of the rear wall to permit the aforementioned substitution. The top ends of the hairpin type of radiant reheater and superheater elements were tied back with more flexible supports.

The aforementioned work was completed November 21, and the unit was brought up to a load of 60,000 kw the following day and continued in operation for nearly four consecutive months at various loads. System load conditions made it necessary to hold the load to around 62,000 kw, but on February 12 and 13 the load was built up first to 70,000, then to 75,000, and finally to 82,000 kw. No unexpected difficulties were experienced. Since then, load conditions have not required carrying more than 65,000 kw, the usual load on the station being 60,000 kw. On March 14, the unit was removed from service for a scheduled inspection.

OPERATING DATA

Fig. 5 indicates the extent to which the Port Washington station has operated since it was first placed in service on October 14, 1935. Table 1 gives the length of the various periods and the reasons for the stoppages.

Table 2 summarizes monthly averages of data assembled every day to aid in economical operation of the plant. Unit design of the station assists greatly in simplifying thermal accounting. Fig. 6 shows that 10,900 Btu per kwhr net is about the ultimate economy level.

As at Lakeside, quantitative readings (temperatures, pressures, and partial heat-balance data) are employed to insure continued efficiency between monthly quantitative measurements of coal used and energy generated. This procedure recognizes that daily coal measurements cannot be made with

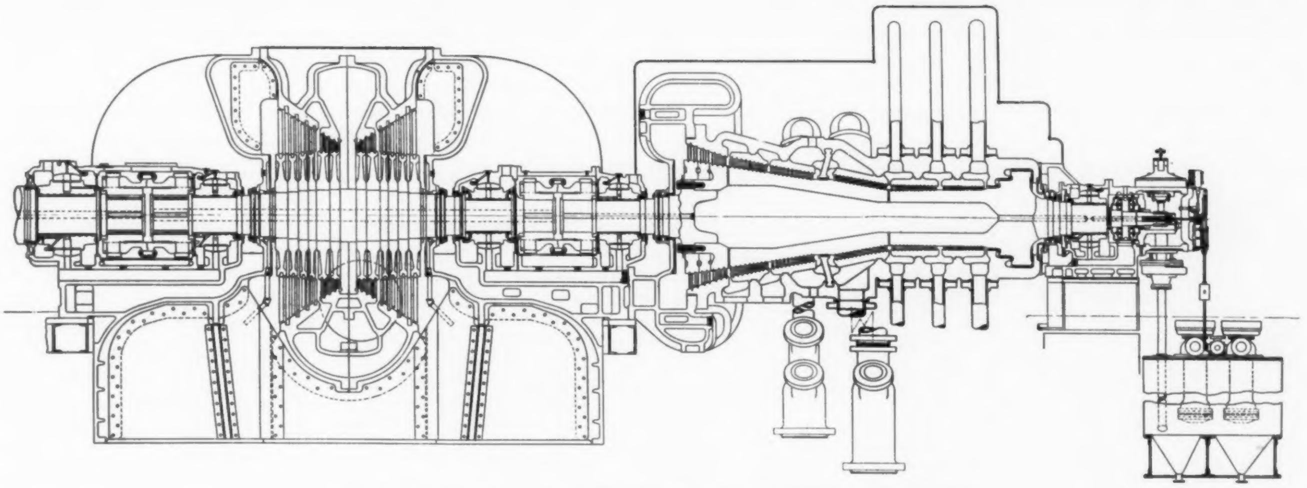


FIG. 3 REHEAT STEAM ADMITTED INTO HIGH-PRESSURE CYLINDER

(Reheat-steam connections part way down the high-pressure cylinder eliminate high-temperature shaft seals. Through the use of reheat, the moisture at exhaust is less than 8 per cent at a load of 62,000 kw and 1 in. abs exhaust pressure.)

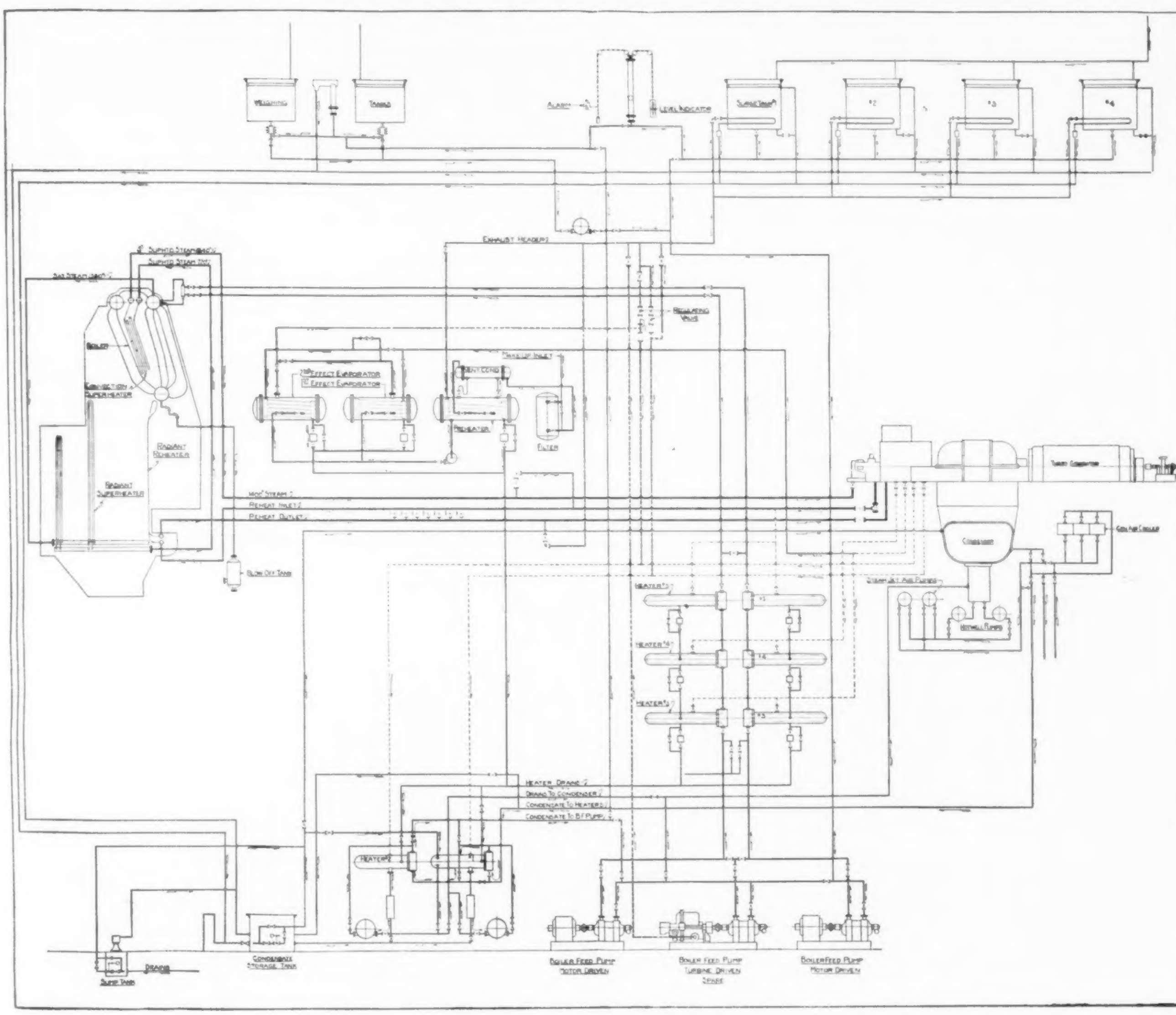


FIG. 4 BASIC FLOW DIAGRAM

(Simplicity of the feedwater system is one of the features of the plant.)

the accuracy that a modern station can be operated. All but pulverized-coal-fineness and heat-value data, which are obtained from mixtures of daily average samples, are assembled daily and reported quarter-monthly. Most values are either chart averages, or averages of data observed hourly.

Turbine-stage efficiencies are calculated daily from averages of hourly stage temperatures and pressure data. These results have been correlated with weighed-water tests, which show that the overall efficiency ratio, including generator losses, is about 84 per cent. These weighed-water tests are made without a trace of extra oxygen appearing in the boiler feedwater and with all five stages of heaters in normal operation. Unit design greatly facilitates accurate testing.

The average first-stage pressure of 946 lb gage shows that the station has been operated fairly near an economical load of the turbine, 60,000 kw. System load conditions have not necessitated maintenance of continuous full load (80,000 kw) on the unit. Its normal operation at 60,000 kw has necessitated an addition of only 12,000 kw to Lakeside's normal stand-by of 48,000 kw, the usual load on its largest unit.

Boiler efficiency, though helped by rather low excess air, has been handicapped throughout by minor air-heater clogging, reasons for which have not been definitely determined. Carbon losses are

TABLE 1 OPERATING PERIODS OF PORT WASHINGTON STATION[a]

Period no.	Date: Start	Date: Finish	Hours run	Kwhr generated	Reasons for stoppage
1	Oct. 14, 1935	Oct. 14, 1935	1	6,900	To adjust to turbine governor
2	Oct. 17, 1935	Oct. 18, 1935	30	621,100	Inspection over week end
3	Oct. 21, 1935	Oct. 25, 1935	103	2,725,000	Reduction in tip area of coal burners
4	Oct. 31, 1935	Oct. 31, 1935	7	214,500	Reduction in reheater surface and completion of construction work
5	Nov. 22, 1935	Mar. 14, 1936	2708	131,970,500	Scheduled inspection
6	Mar. 24, 1936	Apr. 18, 1936	612	28,382,000	Lack of load
7	Apr. 20, 1936	Apr. 25, 1936	137	6,699,000	Lack of load
8	Apr. 27, 1936	May 2, 1936	137	6,749,000	Lack of load
9	May 4, 1936	May 9, 1936	137	6,720,000	Lack of load
10	May 11, 1936	May 15, 1936	113	5,554,000	Replacing valve bonnet on main steam line
11	May 18, 1936	May 23, 1936	137	6,895,000	Lack of load
12	May 25, 1936	May 28, 1936	89	4,504,000	Lack of load and welding leak in joint of reheater element
13	June 1, 1936	June 5, 1936	89	4,734,000	Replacing leaky gaskets under reheater header cover plates
14	June 8, 1936	June 14, 1936	137	7,087,000	Lack of load
15	June 15, 1936	July 3, 1936	449	24,195,000	Reroll tubes in radiant superheater outlet header
16	July 6, 1936	Sept. 1, 1936[b]	1361	74,990,000	
Total			6247	312,047,000	

[a] Both short and long operating periods experienced with this plant have indicated that it is reliable, easily operated, and economical.
[b] Still in operation.

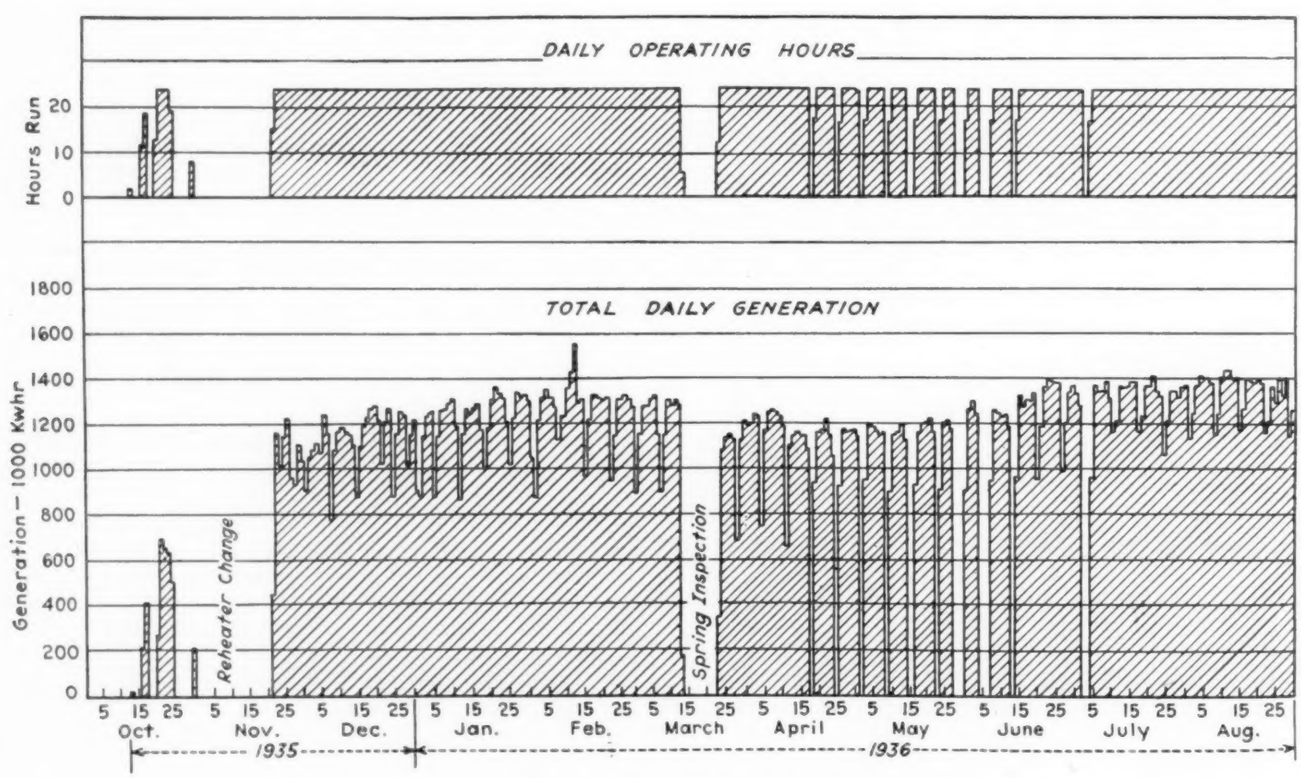


FIG. 5 DAILY OPERATING HOURS AND TOTAL DAILY GENERATION

(Since December 1, 1935, when the plant was considered as going into commercial operation, up to September 1, 1936, the availability factor of the plant has been 92.6 per cent.)

not particularly low, although the average excess air is low. Boiler-feed-pump efficiency is good; the peak is at 70 per cent.

Table 3 shows that heat consumption from the day of starting, including "boiling out" coal to prepare the boiler for operation, averages 11,220 Btu per net kwhr, or 30.5 per cent overall thermal efficiency. November, 1935, output was low and its heat consumption high because during most of the month construction was being completed and the reheater area reduced. During April, May, and June, 1936, the output was reduced by week-end outages which were necessitated by lack of load. A hydroelectric interconnection reduced steam-

TABLE 2 DAILY AVERAGES OF OPERATING DATA

DATE, Month Ending, 1936	Jan. 26	Feb. 24	Mar. 26	Apr. 25	May 26	June 25	July 26	Aug. 26	AVE.
	DAILY AVERAGES**								
COAL, TONS									
To bunker	480	522	459	444	439	468	483	537	479
Pulverized	490	516	476	440	443	468	495	513	480
Burned, apprx.	490	516	474	440	444	468	497	511	480
Mill hours	33.58	35.49	31.94	28.84	29.93	32.86	34.31	34.90	32.73
Mill tons/hr.	14.7	14.5	15.0	15.3	14.8	14.2	14.4	14.7	14.7
Mill system KWH/ton	14.3	14.9	15.3	15.7	16.2	17.0	16.7	16.3	15.8
Moisture, mill in, %	318	3.9	4.1	3.0	3.2	3.6	3.3	3.0	3.5
Moisture, mill out, %	1.8	1.8	1.9	1.6	1.6	1.8	1.7	1.7	1.7
No. 1 Mill Fineness, % through									
200 mesh	63.41	64.69	65.16	68.82	67.68	64.95	65.07	65.45	65.65
100 mesh	89.17	89.79	89.64	91.48	90.72	88.80	89.05	88.65	89.66
48 mesh	97.89	98.39	98.31	98.76	98.65	98.04	98.14	97.91	98.26
28 mesh	99.83	99.87	99.86	90.71	99.90	99.82	99.82	99.77	99.82
20 mesh	99.98	99.98	99.98	99.98	99.99	99.98	99.97	99.96	99.98
10 mesh	100	100	100	100	100	100	100	99.98	100
No. 2 Mill Fineness, % through									
200 mesh	66.33	66.64	65.08	68.46	67.45	66.10	63.23	64.02	65.91
100 mesh	90.70	90.70	89.45	91.24	89.98	89.29	87.90	88.37	89.70
48 mesh	98.31	98.68	98.14	98.60	98.45	98.28	97.76	97.96	98.27
28 mesh	99.85	99.88	99.70	99.68	99.88	99.84	99.75	99.77	99.79
20 mesh	99.98	99.98	99.91	99.98	99.98	99.98	99.94	99.96	99.96
10 mesh	100	100	99.98	100	100	100	100	99.99	99.99
Btu/lb, ash, moist. free	15036	14951	14841	14933	14993	14998	14953	14956	14957
Btu/lb, dry	13588	13523	13505	13598	13713	13701	13716	13710	13632
Btu/lb, as received	12953	12856	12817	13083	13224	13160	13256	13246	13074
Moisture, %	4.7	5.0	5.2	3.8	3.6	3.9	3.3	3.4	4.1
Volatile, %	34.40	34.39	35.31	35.66	36.18	36.35	37.46	37.65	35.93
Fixed carbon, %	55.97	56.06	55.69	55.40	55.28	55.00	54.27	54.02	55.21
Ash, %	9.63	9.55	9.00	8.94	8.54	8.65	8.27	8.33	8.86
Sulphur, %	2.31	2.38	2.52	2.67	2.55	2.58	2.58	2.69	2.53
Ash fusion temp., °F.	2216	2210	2185	2180	2177	2193	2182	2179	2190
PULV. COAL COMP. SAMPLE									
BTU/lb, ash, moist. free	15067	14971	14846	15010	14997	14985	14917	14950	14968
BTU/lb, dry	13607	13568	13502	13683	13653	13683	13633	13669	13625
BTU/lb, as received	13386	13374	13261	13494	13501	13472	13408	13447	13418
Moisture, %	1.6	1.4	1.8	1.4	1.1	1.5	1.7	1.6	1.5
Volatile, %	34.78	34.29	35.12	35.66	35.77	36.48	37.12	37.00	35.78
Fixed carbon, %	55.53	56.34	55.83	55.50	55.27	54.83	54.27	54.43	55.25
Ash, %	9.69	9.37	9.05	8.84	8.96	8.69	8.61	8.57	8.97
Sulphur, %	2.23	2.25	2.47	2.57	2.56	2.63	2.68	2.86	2.53
BOILER ROOM									
Steam, million lb.	9.430*	9.956*	9.301*	8.540	8.745	9.375	9.923	10.196	9.433
Feedwater, mil. lb.		9.759	9.214	8.532	8.674	9.347	9.746	9.964	9.319
Ave. output, thd. #/hr.	393*	415*	395*	359	386	404	416	425	399
Hours steaming	24.00	24.00	23.52	23.78	22.65	23.18	23.83	24.00	23.62
Hours banked	0	0	0.12	0	0	0.47	0.24	0	0.10
% excess air	26	22	24	23	20	21	18	19	22
Pressure, lb. G.	1200	1202	1196	1196	1197	1226	1248	1249	1214
Feedwater temp. °F.	368	369	362	368	378	388	389	390	376
Feedwater press. #/G	1480*	1470*	1466*	1494	1464	1451	1408	1372	1451
B.F. pump eff. % actual	64.5*	64.8*	65.8*	63.9	64.7	66.0	66.0	65.4	64.9
B.F. pump eff. % stand.	66.1*	65.9*	66.1*	66.9	67.4	66.0	64.9	64.4	66.0
% comb. in fly ash						13.68	14.08	12.44	13.40
Exh. to htrs., thd. lb.			.30	13.4	22.6	18.0	28.5	43.9	21.1
Steam temp., °F.									
Rad. suphtr. out	672	677	672	672	672	676	674	669	673
Con. suphtr. out	819	825	827	829	829	830	835	834	829
Reheater in	529	540	539	531	528	527	530	531	532
Reheater out	811	821	821	827	826	833	836	836	827
Gas temps. °F.									
Air heater in	730	741	736	711	720	729	737	741	731
Air heater out	378	383	383	360	365	373	384	393	377
Drop	352	358	353	351	365	356	353	348	353
Air temp., °F.									
Air heater in	119	128	146	156	150	161	164	173	151
Air heater out	521	550	539	546	549	547	553	545	544
F.D. fan in	105	107	115	114	115	117	120	121	114
Rise	416	443	424	432	434	430	433	424	430
% Air thru heater	95	91	94	91	92	93	92	93	93
Htr. Perform. % of std.	86	87	89	103	101	98	95	90	94
TURBINE ROOM									
Ave. load, KW/hr.	49639	52448	50454	46774	48757	51871	53880	54526	51019
Temperatures, Deg. F.									
Throttle	817	821	821	823	823	822	828	828	823
1st. inlet	794	802	801	798	802	804	812	815	804
Reheater in	542	551	548	539	537	532	536	537	540
Reheater out	810	818	816	819	816	821	826	827	819
No. 3 heater	486	489	487	483	482	487	487	488	486
Pressures, lb. G.									
Throttle	1164	1163	1162	1162	1161	1187	1209	1208	1177
1st. inlet	887	935	918	858	918	979	1024	1050	946
Reheater in	234	252	245	223	237	251	263	269	247
Reheater out	208	223	217	199	210	223	234	239	219
No. 3 heater	29.9	33.0	31.9	27.9	30.6	33.9	36.0	37.1	32.5
Stage Efficiencies, %									
1st in. to rehtr in.	74.6	74.6	74.8	76.3	77.9	78.6	80.1	79.7	77.1
Rehtr. out to No. 3 htr.	83.6	84.0	83.7	85.1	85.3	85.7	86.3	84.5	85.0
Both	79.9	79.9	79.9	81.3	82.0	82.6	83.6	83.5	81.6
Cir. water out, F.	40.7	40.2	39.5	41.7	47.7	54.8	66.3	73.1	50.5
Cir. water in, F.	35.7	35.6	35.4	37.9	44.0	51.0	62.7	69.5	46.5
Cir. water rise, F.	5.0	4.6	4.1	3.8	3.7	3.8	3.6	3.6	4.0
Condensate, F.	51.1	49.9	48.9	49.5	54.6	61.4	72.6	79.2	58.4
Exh. Press. "Hg. Abs.									
Actual	.43	.39	.36	.42	.50	.55	.82	1.02	.56
Air pump inlet	.40	.37	.35	.39	.45	.54	.77	.98	.53
Air leakage, CFM	2.4	2.0	2.6	3.2	3.5	4.4	3.9	3.2	3.2
ELECTRICAL									
Output, gross, 1000 KWH	1171.6	1240.8	1179.5	1116.6	1132.8	1228.9	1302.2	1329.1	1212.7
Output, net, 1000 KWH	1108.1	1174.7	1116.4	1054.8	1070.6	1164.7	1236.6	1262.8	1248.6
Auxiliaries, 1000 KWH	63.5	66.1	63.1	61.8	62.2	64.2	65.6	66.5	64.1
Auxiliaries, %	5.5	5.4	5.4	5.5	5.5	5.2	5.0	5.0	5.3
% for coal prep.	.60	.62	.64	.63	.64	.63	.64	.63	.63
% for B.R. fans	.92	.92	.98	.97	.98	.98	.95	.94	.95
% for B.F. pumps	1.71	1.68	1.58	1.66	1.63	1.57	1.52	1.51	1.61
% for circ. pumps	1.23	1.16	1.23	1.29	1.19	1.13	1.09	1.07	1.17
% for miscellaneous	1.04	1.02	.97	.95	1.06	.87	.80	.88	.95
Station heat consumption, BTU per KWH									
Gross	10721	10655	10804	10339	10411	10373	10328	10314	10484
Auxiliaries	615	600	640	607	618	592	552	543	592
Net	11336	11255	11444	10946	11029	10965	10880	10857	11073

* Corrected to agree with new meter correction factor used since April.
**Except Mill Fineness, Pulv. Coal Comp. and % Comb. in fly ash items.

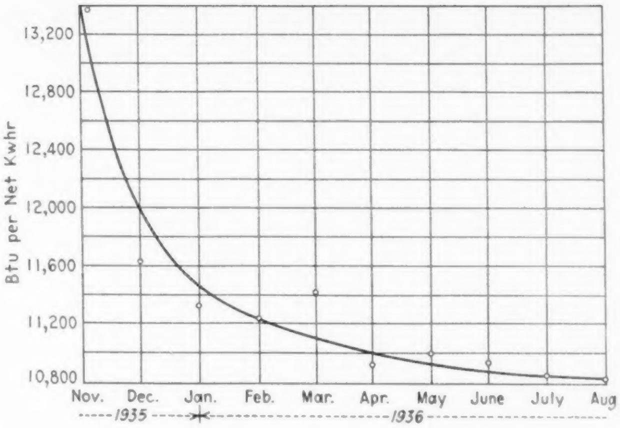


FIG. 6 CONSISTENTLY GOOD STATION PERFORMANCE

(Gains made possible by reheat aid materially in obtaining the record of better than 11,000 Btu per net kwhr.)

plant load to 20,000 kw during early morning hours on Sundays and Mondays.

OPERATING FLEXIBILITY

After the 30-hr week-end shut-downs of April and May, due to lack of load, the unit was usually synchronized within 45 min after warming was started. Axial expansion of the cylinder, as measured at the thrust end, did not increase until after the load was assumed. In fact, the effect of cooling at the low-pressure end was greater than that of the heating at the inlet end before synchronizing, causing the unusual effect of shortening of the cylinder when warming. During a 30-hr shut-down, total expansion from cold decreased from 0.82 to 0.50 in., representing one-third cooling.

Two hours previous to initial shut-downs, steam temperatures were slowly decreased 100 F by stopping end burners and using additional excess air. Resulting slight steam leakage through the leak-off steam-pipe joints caused discontinuance of this practice, after which no effort was made to lower the temperatures before stopping. Apparently, the cylinder bolting cooled less rapidly than the flanges, even though the latter were cooled only 50 F per hour.

Turning-gear rotation at 25 rpm was employed throughout the 30-hr shut-down periods. With the exception of the initial starting, when the vacuum was not high enough and too long a period was taken for heating, vibration has been absent at all times. When on the turning gear, lubricating oil is supplied by a motor-driven pump.

Both the throttle- and reheat-steam temperatures are increased as nearly as practicable to the rate of 100 F per hr when starting. One hour's lag of bolt temperatures after flange temperatures, for instance, would result in 20,000 lb additional stress on the bolts. Actual measurements showed, however, only a 10 F bolt and flange difference. The heavy flanges lagged about 200 F behind the steam and adjacent pipe temperatures, both in the 1300-lb and the reheater-outlet 825 F piping.

A load of 15,000 kw was, on a few occasions, carried for several hours and a load of 20,000 kw for many hours. At the former load, inequality of flow through the two reheater outlets varies and causes as much as 100 F differences, but the mixture of steam to the turbine remains near the standard value of 825 F.

The steam-driven boiler feed pump is used at loads below 16,000 kw and when starting and stopping. As with the Lakeside high-pressure pumps, first signs of instability appear

at about one-quarter to one-third output by fluctuation of the discharge pressure. At these low loads the discharge pressure exceeds 1800 lb per sq in., for the motors are of constant-speed design.

The 30-hr shut-downs have proved that the unit will be practicable throughout its lifetime. When later relegated to peak-load operation and daily outages, it will operate as satisfactorily as a nonreheat machine. The heavy high-pressure cylinder, not the reheat section, determines operating limitations.

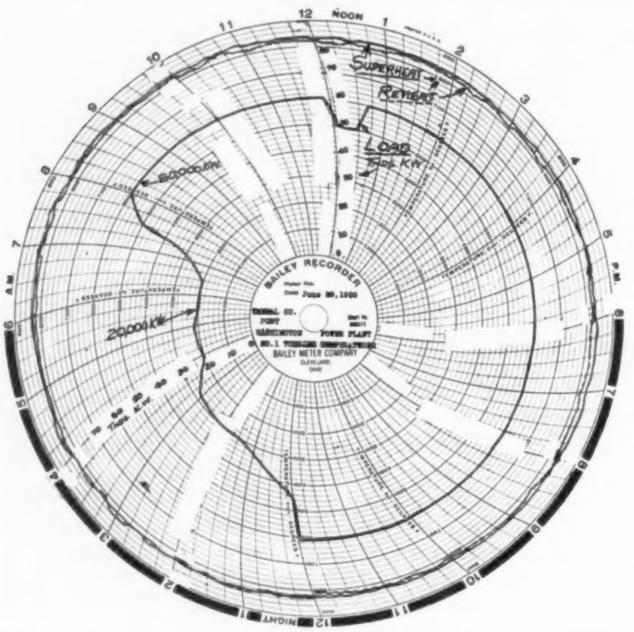


FIG. 7 CONSTANT STEAM TEMPERATURE IN SPITE OF A 3-TO-1 LOAD VARIATION

(The chart illustrates how nearly fixed are the temperatures of both the superheat and reheat steam entering the turbine at various loads. The control of these temperatures has aided materially in obtaining efficient performance and low operating costs.)

STEAM-TEMPERATURE REGULATION

Superheat and reheat temperatures are essentially nonvariable from 20,000 to 80,000 kw, due to the partial use of radiant surfaces. Fig. 7 shows a typical chart illustrating this point. Hourly temperature readings at the turbine never suggest the occurrence of 3-to-1 load variations, and hundreds of readings are recorded consecutively with no single reading falling below 800 or above 840 F. The design averages of 825 F for superheat and 825 F for reheat are maintained without closely approaching the maximum of 850 F. Considering that nearly half as much heat is added in the superheater and reheater as in the boiler this closeness of inherent regulation is unusual.

Deliberate adjustment of superheat and reheat temperatures is always possible. Permanently installed soot blowers permit a 10 per cent variation in heat absorption; slowing of end burners reduces superheat; and increase of excess air reduces reheat without affecting superheat. Never have steam temperatures been higher than desired.

Maintenance of uniform steam temperatures is considered a vital necessity for high reliability and good economy.

INSURING CONTINUITY OF SERVICE

That unit design when employing relatively large equipment demands especially reliable auxiliary services, is obvious. Two lines of defense against outages due to auxiliary failures must be employed in practically all cases.

Vital auxiliaries are dual, and are served by energy from two sources. One auxiliary transformer serves half of the important auxiliaries and is connected to the generator leads, thus permitting their continued service should the main generator switch, for instance, be opened temporarily. The other set of auxiliaries, served from the station bus, may receive energy from outside the station or from other units when later installed. If either transformer fails, its load is automatically assumed by the other.

Use of the bin system of firing, whereby coal can be fed to the furnace by direct-current motors energized by the station batteries (also used for controls and for emergency excitation and lighting), permits sufficient steam generation with the aid of natural draft to sustain the main unit at speed without auxiliary current. When most needed, in the case of low frequency during emergencies, coal-firing capacity does not decrease with the cube of the system speed, as with direct firing. Thus, provision is made for emergencies as well as for insuring against their occurrence.

Continuous circulating-water supply, a single vulnerable service for several units in any station, is insured by a power-operated trash-rack rake of high capacity, a 100 per cent recirculating system for coping with serious ice troubles, and traveling screens that are located for good attention, arranged as high-capacity fish elevators, and further equipped with a differential level alarm that warns of impending stalling.

Outage of either of the two circulating pumps, induced- or forced-draft fans, or primary-air fans will not cause total failure of their particular service, for backward flow through the idle auxiliary is automatically stopped. Unless provision is made for this rapid automatic check-valve type of action, recirculation so cripples the active auxiliary that its net capacity is nearly zero. Low-voltage relays on each motor close the circulating-pump discharges and unbalanced louver dampers prevent recirculation through idle fans.

TABLE 3 MONTHLY OUTPUT AND HEAT CONSUMPTION DATA

Year	Month	Output, kwhr Gross	Auxiliary	Net	Heat consumption, Btu per kwhr Gross	Auxiliary	Net
1935	Oct.	3,353,000	431,600	2,921,400	14,215	2,100	16,315
	Nov.	3,961,000	359,700	3,601,300	12,159	1,214	13,373
	Dec.	33,853,000	1,969,000	31,884,000	10,962	677	11,639
1936	Jan.	36,302,000	1,969,929	34,332,071	10,721	615	11,336
	Feb.	35,938,000	1,914,502	34,023,498	10,655	600	11,255
	Mar.	24,879,000	1,390,674	23,488,326	10,804	640	11,444
	Apr.	32,333,000	1,795,342	30,537,658	10,339	607	10,946
	May	28,031,000	1,570,718	26,460,282	10,411	618	11,029
	June	28,033,000	1,513,510	26,519,490	10,373	592	10,965
	July	37,670,000	1,911,608	35,758,392	10,328	552	10,880
	Aug.	41,189,000	2,061,043	39,127,957	10,314	543	10,857
Totals.......		305,542,000	16,887,626	288,654,374	....	...	....
Averages.....		....	......	....	10,600	620	11,220

(An ultimate of about 10,900 Btu per net kwhr on an annual basis, representing 31.3 per cent overall thermal efficiency, appears to be the best economy of the present station. Including coal for boiling out the boiler initially, its heat consumption to date, August 26, 1936, has averaged 11,220 Btu per net kwhr or 30.5 per cent efficiency.)

A steam-driven boiler feed pump and a house-service pump act as stand-by for emergencies and as spares. Both can be started rapidly under all conditions. They can be operated at full load even though boiler pressure falls below half its normal value. All house-service pumps are equipped with dual strainers that can be cleaned alternately. Alarms warn immediately of low feedwater or house-service water pressure, for little time should be lost when operating at the higher capacities and with the lesser water storage of modern boiler equipment.

Excessive condensate demands, due to unpreventable leaks, will not immediately hazard operating continuity because 1,000,000 lb of condensate storage exists 68 ft above the boiler feed pumps and is drawn upon automatically at any time.

All controls and meters have been grouped to assist rapid and intelligent operation in emergencies. Automatic controls, when used, are simply supplementary to save labor or time in emergencies. The vital duty of boiler-water-level regulation is not automatic. Aids to hand regulation completely removed the need of entrusting it to mechanisms that are oftentimes the cause of serious troubles.

Dual hot-well and air-removal pumps are employed, either one of which can carry full load. Hotwell pumps are driven by variable-speed motors to assist in dissolved-oxygen control.

The low-pressure extraction heaters are arranged with by-passes while the high-pressure heaters are in pairs. It is interesting to note that a rare outage of all heaters simultaneously might cause shut-down of the plant, for superheated steam temperatures would become much too high because of the greatly decreased station water rate. Twenty-five per cent of the throttle steam is extracted for feedwater heating.

Gland-water supply to the turbine is provided from three sources, the third of which is never failing though at a slightly lesser pressure than the others. Readily checked alarms are used in this and other vital cases.

Perhaps the anticipation of troubles experienced in previous installations has helped prevent their occurrence in this plant, for its operation to date has been of high reliability.

FIG. 9 FURNACE INTERIOR AFTER NEARLY FOUR MONTHS OF CONTINUOUS OPERATION

(Only light deposits of fragile ash appeared on the surfaces after this long run. One of the side-wall radiant superheater panels can be seen at the back in this picture, the front waterwall at the right, and the radiant reheater with its waterwall panel at the left.)

EQUIPMENT PERFORMANCE

Reheater. Mention has been made of the difficulty encountered in holding the reheat temperature down during the initial periods of operation. Provision had been made in the design of the reheater, which is of the radiant type and located on the rear furnace wall, to permit adding to or subtracting from the surface by adding or removing elements and substituting waterwall elements. A waterwall panel consisting of 22 elements was installed initially in the center of the rear wall, so that it was a relatively simple matter to add elements by rolling them into the headers that were provided for this purpose. A total of 12 per cent of the original reheater surface was removed. At the same time the front-wall air-port area was readily increased two thirds, and this, together with a contemplated change in burner-tip area, provided for better distribution of the flame in the furnace. The net result of all these changes was the lowering of the re-

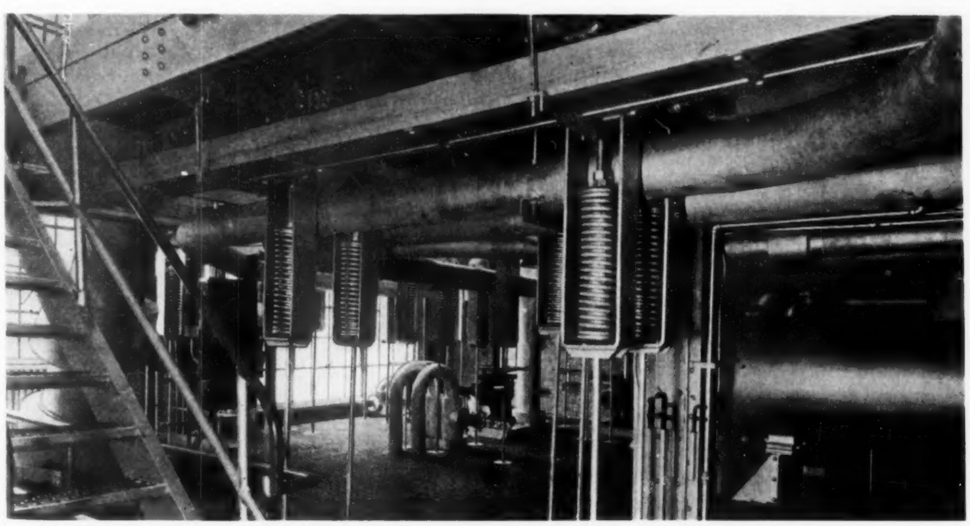


FIG. 8 COIL-SPRING PIPE HANGERS

(Flexibility to high-pressure high-temperature pipe is provided through liberal use of coil-spring pipe hangers.)

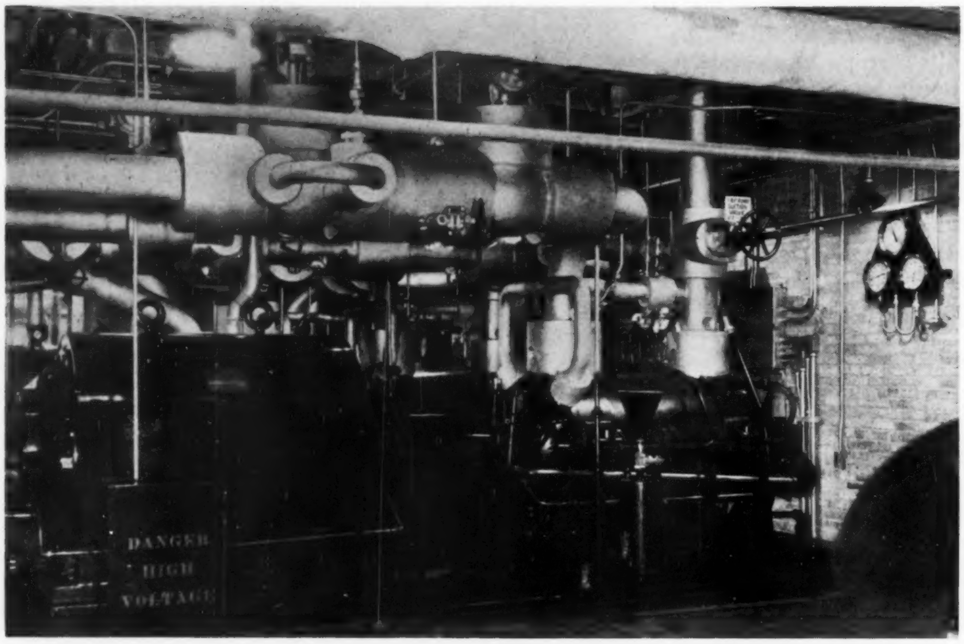


FIG. 10 HIGH-PRESSURE BOILER FEED PUMP

(This eight-stage centrifugal pump is driven by a 1250-hp constant-speed motor, operating at 3600 rpm. Another like it is also motor driven while a third is driven by a 1250-hp steam turbine.)

heat temperature to the value that is considered desirable.

At the time of making the change to the rear-wall reheater elements, the supports of some of the radiant elements, both superheater and reheater, were modified. It was found that some of the hairpin-type reheater elements had slightly bowed out into the furnace at the top of the elements, probably because of high strength, high thermal expansion, and low conductivity of the KA2ST elements. More flexible tiebacks rectified the difficulty and no trouble has been experienced since. Four butt welds of these high-alloy tubes have leaked slightly, but have not caused any operating inconvenience.

Corrugated monel-metal handhole plate gaskets were found positively unsuited for 825-F service. They cracked at stress points, and some blew out after 4000 hours' service. Mild-steel gaskets were used in their place.

Piping. The piping in the plant has performed without any sign of distress. It was erected to allow for proper expansion by pulling two thirds of the required expansion between anchor points when cold, so that when it is heated to the operating temperature it is under slight compression. In order to cause uniform stress of bolts in high-temperature lines, all were stressed to 50,000 lb per sq in. by elongating them 0.002 in. per one inch of free length. Each bolt was measured with a micrometer caliper before and after pulling up.

The springs shown in Fig. 8 illustrate the numerous flexible supports that have been provided for the piping.

A cast-steel valve bonnet on the high-pressure high-temperature steam line to the turbine was found to have a crack in it when the bolts were pulled up after investigating a steam leak. The material is 4 to 6.5 per cent chrome with 0.4 to 0.65 molybdenum. Undoubtedly, the casting was defective. This failure emphasizes the fact that progress in the more difficult fabrication of materials, in this case alloy steel, must keep pace with progress in the art of generating power by steam, or else the purpose of these inherently better materials will be defeated.

An experience worthy of note was one which occurred at a 1300-lb joint at the turbine. Ambrac metal, consisting essentially of 70 per cent copper and 30 per cent nickel, had been used as gasket material between "phonograph" faces. Creep of the gasket material into the serrations caused loosening of the bolts and ultimate leaking of the joint. This experience illustrates the need for following up on gasketed joints at high temperatures that permit plastic flow of the gasket material.

Furnace. Relatively low furnace temperatures are obtained by employing the large hopper-bottom furnace with large heat-absorbing surfaces on all sides of the furnace which result in the prevention of any accumulation of troublesome ash deposits. This permits month after month operation at continuous rating, if necessary. Fig. 9 shows the inside of the furnace after nearly four months of continuous operation. The deposits that are visible on the surfaces are fragile "whisker" ashes that eventually fall from their own weight. The surfaces were not cleaned before this picture was taken. The first row of boiler tubes has never been lanced.

Feedwater System. The feedwater system employed is simple in spite of five stages of feedheating. In place of the two, and sometimes three, stages of pumping that have been used for boiler feeding in plants of this type, a single stage of pumping feeds the boiler directly, taking reserve condensate from a liberal overhead storage. Because of its simplicity, the system is unusually reliable and requires no correlation of several pumps, which is an important consideration, particularly in times of emergency.

A "to-condenser" water rate of 5.5 lb per kwhr emphasizes the gains made possible through feedwater heating. In order to eliminate difficulties that might be encountered due to handling high-temperature water in the boiler feed pumps, three stages of extraction heaters were placed on the discharge side of the pumps. The pumps handle relatively low-temperature condensate at low suction pressure, thus adding materially to their reliability. The power savings realized by pumping feedwater before it expands to higher specific volumes in the feedwater heaters is appreciable.

Two sets of high-pressure extraction heaters are used, one on each of two feed lines to the boiler. Each feed line has a separate motor-driven high-pressure pump with a spare steam-driven pump so connected that it can be substituted in either line. One of the motor-driven pumps is shown in Fig. 10. Two feed lines to the boiler are used because better parallel operation of centrifugal feed pumps can be obtained when they are discharging through heaters and piping before their pressures are equalized.

In order to make the higher three stages of feedwater heaters reliable, usual bolted-joint construction was abandoned and boiler manhole practice was followed. Thus the high water

(*Continued on page 728*)

DOMESTIC OIL BURNERS

Description of Common Types of Burners and Results of Laboratory Tests on Them

By A. H. SENNER

DIVISION OF STRUCTURES, BUREAU OF AGRICULTURAL ENGINEERING

BEGINNING nearly fifteen years ago, the Federal Bureau of Home Economics received inquiries indicating a generally increasing interest in the use of automatic oil burners for heating the home. To meet the demand of prospective purchasers of domestic oil burners for reliable information, the Division of Agricultural Engineering, now the Bureau of Agricultural Engineering, U. S. Department of Agriculture, in cooperation with the Bureau of Home Economics tested a number of oil burners of different designs and issued Department Circular No. 405, "The Domestic Oil Burner." This publication first appeared in January, 1927, was revised and reprinted in January, 1930, and is now being revised again as Circular 406, "Oil Burners for Home Heating," to keep abreast of the rapid development of new equipment and accessories used in connection with domestic oil burners. Circular 406 is nontechnical in nature; the technical phases of the domestic-oil-burner study have been treated in U. S. Department of Agriculture Technical Bulletin 109, "A Study of the Oil Burner as Applied to Domestic Heating," now out of print.

Early in the study it became apparent that some of the conventional ideas regarding combustion did not hold true in the burning of oil in the small domestic furnaces, and, in order to study this phase of the problem more thoroughly, in 1927 the research work was transferred from the Washington laboratories to the laboratories of the mechanical-engineering and gas-engineering departments of the Johns Hopkins University. Since then that institution has cooperated in the domestic-oil-burner work. The Bureau of Agricultural Engineering acknowledges the assistance of A. G. Christie and J. C. Smallwood of the mechanical-engineering department and W. J. Huff and D. T. Bonney of the gas-engineering department. In this connection, also, a study of the chemistry of combustion of oil fuel in small furnaces was performed by Theodor Theodorsen while serving as an instructor in mechanical engineering at Johns Hopkins. The test results were submitted by Theodorsen in partial fulfillment of the research requirements for the degree of Doctor of Philosophy. The work of Theodorsen was sponsored by the American Oil Burner Association and the author acted as general supervisor. The laboratory work necessary for the acquisition of material for the most recent revision of Department Circular No. 405 has only recently been completed in the laboratories of the Johns Hopkins Engineering School.

FUELS FOR DOMESTIC OIL BURNERS

The domestic-oil-burner fuels are distillates of crude petroleum. Early in the history of automatic domestic oil burners the several fuels were distinguished one from another by their density or "gravity." They are now known commercially as domestic fuel oils Nos. 1, 2, 3, etc., and no mention of gravity is made in the specifications for the several grades. Sometimes the fuels are referred to as light, medium, and heavy domestic oils, and light, medium, and heavy industrial oils; but again such a classification implies the "gravity" of the oil, and we now know that the gravity is not necessarily of significance as regards its suitability for use in a domestic oil burner. Table 1, taken from Commercial Standard CS 12-35, Fuel Oils,[1] published by the National Bureau of Standards, gives the detailed requirements for various grades of domestic oil-burner fuels, including the Nos. 4, 5, and 6 which are not ordinarily supplied to full automatic domestic oil burners. According to the most recent listing of the National Board of Fire Underwriters no automatic oil burner for the average-size dwelling has been listed for the use of oil heavier than No. 3. The oils Nos. 1 and 2 are generally consumed by the vaporizing types of burners or those types which combine both atomization and vaporization. This includes the so-called retort type of burner, which uses the No. 2 fuel, and the vertical-rotary, blue-flame, wall-wiping type. The No. 3 oils are utilized satisfactorily by the so-called "gun" or pressure-atomizing types. When the small domestic oil burners were listed by the Underwriters Laboratories to burn the No. 4 fuel, such oil was recommended principally for the so-called air-atomizing or emulsifying types. In spite of the fact that they are not now listed to burn the No. 4 oil such units undoubtedly can still utilize satisfactorily much of the No. 4 fuel which is being marketed today.

The requirements given in the table are good general statements of the characteristics of the several types of fuels, and oils meeting the requirements of the several grades generally prove satisfactory for the burners designed to handle them. There is, however, still some lack of knowledge as to which characteristics of fuels are imperative for satisfactory performance, particularly in the vaporizing types of burners. For example, it has been suspected for some time that more information than that given by the aforementioned Commercial Standards for No. 2 fuels may be necessary in order to provide oils which will assure satisfactory combustion and a minimum of soot and residue in the furnace and heating passages of the boiler when such fuels are supplied to the burners depending upon the vaporizing principle. Some admirable work has been done in this direction by the Shell Oil Company in their research laboratories at Sewaren, N. J., and additional work has also been undertaken by the Sun Oil Company and others. The Shell laboratories are reported to be convinced from their work, that, among other things, instead of performing the Conradson carbon residue test in the conventional manner, the carbon residue of the heaviest 10 per cent of the oil should be measured in determining the significant carbon residue for a given fuel, particularly when consumed by the vaporizing type

Contributed by the Fuels and Oil and Gas Power Divisions for presentation at the Annual Meeting, New York, N. Y., Nov. 30 to Dec. 4, 1936, of The American Society of Mechanical Engineers.

[1] For sale by the Superintendent of Documents, Government Printing Office, Washington, D. C. Price 5 cents. In addition to the table of requirements for the oil fuels this publication gives the method of test, history of the project resulting in the publication of the standards, etc.

TABLE 1 DETAILED REQUIREMENTS FOR FUEL OILS[a]

No.	Grade Description	Flash point, F Min	Flash point, F Max	Pour point, F Max	Water and sediment, per cent Max	Carbon residue, per cent Max	Ash, per cent Max	Distillation temp, F: 10-per cent point Max	Distillation temp, F: 90-per cent point Max	Distillation temp, F: 90-per cent point Min	Distillation temp, F: End point Max	Distillation temp, F: End point Min	Viscosity: Saybolt universal, at 100 F, sec Max	Viscosity: Saybolt universal, at 100 F, sec Min	Viscosity: Saybolt furol, at 122 F sec Max	Viscosity: Saybolt furol, at 122 F sec Min
1	A distillate oil for use in burners requiring a volatile fuel	100 or legal	150	15[b]	0.05	0.02	..	420	...	...	600	...	...	...	...	...
2	A distillate oil for use in burners requiring a moderately volatile fuel	110 or legal	190	15[b]	0.05	0.05	..	440	620	...	...	600	...	...	...	...
3	A distillate oil for use in burners requiring a low-viscosity fuel	110 or legal	200	15[b]	0.1	0.15	..	...	...	620[c]	...	...	70	...	...	...
4	An oil for use in burners requiring low-viscosity fuel	150	...	[d]	1.0	..	0.1	...	...	...	...	...	500	70[e]	...	...
5	An oil for use in burners equipped with preheaters permitting a medium-viscosity fuel	150	...	...	1.0	..	0.15	...	...	...	...	...	...	...	100	25
6	An oil for use in burners equipped with preheaters permitting a high-viscosity fuel	150	...	...	2.0[f]	..	..	...	...	...	...	...	...	...	300	100[g]

[a] Recognizing the necessity for low-sulphur fuel oils used in connection with heat-treatment, nonferrous-metal, glass, and ceramic furnaces and other special uses, a sulphur requirement may be specified in accordance with the following table:

Grade of fuel oil Number	Sulphur (max), per cent
1	0.5
2	0.5
3	0.75
4	1.25
5	No limit
6	No limit

Other sulphur limits may be specified only by mutual agreement between the buyer and seller.

[b] Lower or higher pour points may be specified whenever required by conditions of storage or use. However, these specifications shall not require a pour point lower than 0 F under any conditions.

[c] This requirement shall be waived when the carbon residue is more than 0.07 per cent and less than 0.15 per cent.

[d] Pour point may be specified whenever required by conditions of storage or use. However, these specifications shall not require a pour point lower than 15 F under any conditions.

[e] This requirement shall be waived when the carbon residue is more than 1.0 per cent.

[f] A deduction in quantity shall be made for all water and sediment in excess of 1.0 per cent.

[g] This requirement shall be waived when the carbon residue is 4 per cent or more.

of burner. In addition to this, increased effort has been made to learn more about the corrosive effect of oils in storage tanks and other metallic parts of the oil-burning system, the causes for strainer clogging, and many other detailed problems too numerous to mention. Beyond doubt steady improvement in the grades of oils will be evinced as time and work proceed. Another effort which is almost certain to bear fruit is that designed to reduce the number of grades of fuels by elimination of certain of those which may prove unnecessary as burner design becomes more standardized.

CLASSIFICATION OF DOMESTIC OIL BURNERS[2]

There are on the market a number of burners for use in house heaters varying in the method employed in preparing the fuel for combustion. In general they operate upon one or the other of two broad principles, namely, the vaporization or atomization of the oil prior to burning. Burners may be classed, then, generally as either vaporizing or atomizing, but there is one important class of burners which combines both vaporization and a certain degree of atomization. (This is the so-called blue-flame rotary type which will be referred to again later.)

VAPORIZING TYPE

In the earlier issues of U. S. Department of Agriculture Circular No. 405 and in Technical Bulletin No. 109, the vaporization type of oil burner referred to was the old-fashioned spreader-plate type. This burner consisted merely of one or two rough castings set inside the furnace, one of which served to volatilize the oil. These two bulletins stated that the combustion and general type of service obtained from the spreader-plate vaporizing burners were far from satisfactory. It is important therefore to appreciate the fact that the class of vaporizing burners now generally employed in domestic heating, and to which the following discussion refers, is entirely different from the old spreader-plate burner; the character of service obtained from the newer vaporizing burners is of a much higher order than that obtained from the vaporizing burners discussed in the earlier publications of the Bureau of Agricultural Engineering.

[2] Much of this description of burner types is taken verbatim from Circular No. 406, U. S. Department of Agriculture.

There are two principal types of true vaporizing domestic oil burners in use at the present time, although it must be borne in mind that with so many modes of burning oil, some of which are highly ingenious, it is impracticable to include references to all variations of the principal types in a limited discussion such as this.

POT AND RETORT TYPES

The first of these two principal vaporizing types is that kind which premixes air and oil vapor, before combustion, by means of a pot or retort and a system of air distribution. A partial cross-sectional view of a burner of this type is shown in Fig. 1.

In this burner the oil and air are delivered to the combustion chamber by means of a system consisting of a blower, motor, and oil-control valves, most of which mechanism is located under the hood *h*. The air is delivered to the mixing chamber or "retort" through the delivery tube *g*, and the oil is fed to the chamber through oil line *f*. The gas pilot tip *e* provides the ignition on the gas-ignition type of burner illustrated, although electric ignition is also offered by the manufacturers. The oil flowing to the bottom of the combustion chamber is vaporized and premixed with air supplied positively by the blower, principally through the air distributor *b*. By premixing is meant that the vaporized oil and air are principally mixed with the air required for combustion before ignition takes place. The flame *a* burns well out of the chamber and the chamber itself does not become very hot, because of the circulation of air around it (some air is also delivered through ports *c*), and because of the presence of the evaporating oil on the bottom of the chamber. Only the mixing chamber and a small portion of the tube *g* project into the boiler, and the

mechanism housed by cover *h* is external to the boiler.

Another of the two principal types of vaporizing burners is one which utilizes a mineral wick in the bottom of the pot and an air distributor for mixing the oil vapor and air in the proportions required for combustion. One of the important differences between the vaporizing burners and atomizing burners is the fact that since the former type operates by boiling or vaporizing the fuel, such burners must be supplied with a relatively free-boiling fuel and one which leaves only a relatively small solid residue after burning. This means in practice today that vaporizing burners are limited to the use of fuel not heavier than the No. 2 of the commercial grades.

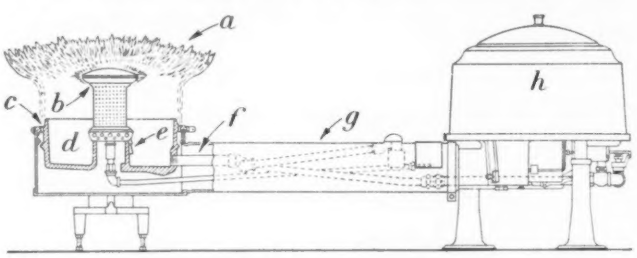


FIG. 1 POT TYPE OF VAPORIZING OIL BURNER

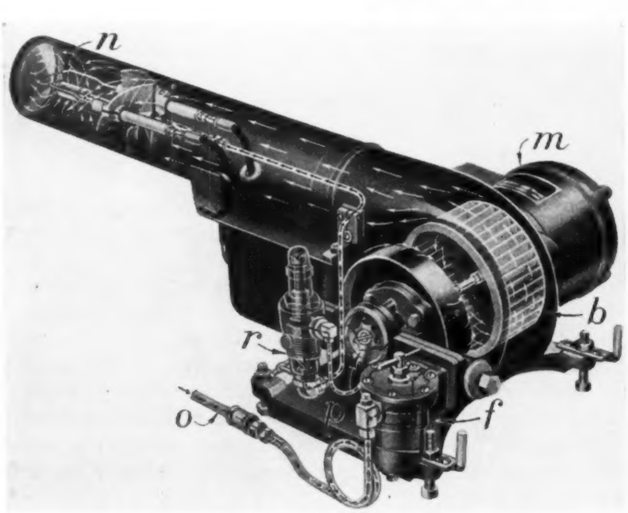


FIG. 2 GUN TYPE OF VAPORIZING OIL BURNER

There is one interesting application of the vaporizing burner to automatic heating in which the flame is not ordinarily entirely extinguished when the room temperature has been satisfied, but rather in which there is a so-called "high-low" control of the flame resulting in a more nearly continuous operation. The proponents of this type of burner maintain that in this manner greater comfort is realized because of the more nearly continuous input of heat to the heating system, which is no doubt true. Also, they claim some improvement in economy because of what might be termed the "throttling" effect of this type of control. In spite of the fact that this mode of operation would seem theoretically correct, only a small fraction of the domestic oil burners of today operate in this fashion.

ATOMIZING TYPE

The atomizing type of oil burner may be subdivided into the most common type which breaks up the oil by forcing it through a small orifice or nozzle and those which atomize the oil by other spray devices which have generally the same effect.

THE GUN OR PRESSURE-ATOMIZING TYPE

In the commonest type of atomizing burner the oil is put under pressure and forced through a small nozzle opening to break it up into minute particles so that it enters the furnace as a vapor spray. Together with this, air is supplied by a blower or pump and so regulated as to bring about the proper mixture of the air and fuel. This type of burner is most familiar to the general public as the so-called "gun" type. (The term "pressure atomizing" burner would be more exact and it is probable that in the future this term will be used more commonly.)

Referring to Fig. 2, the operation of the so-called "gun" burner is as follows: Oil is fed to the burner from the oil-storage tank through the line *o*, passing through the filter *f*, and thence to the oil pump *p*. The pump forces the oil through the pressure-regulating valve *r*, and from here the oil is delivered at a constant pressure, generally about 100 lb per sq in., to the nozzle *n*, from which point it is sprayed into the furnace in a fine mist, at the same time being mixed with air which is supplied by the fan *b*. The motor *m*, only a small fraction of a horsepower, supplies the required power.

AIR-ATOMIZING TYPE

The atomization of the oil may be effected by the use of the energy contained in air when compressed to certain pressures and this gives the general type known as the "air-atomizing" burner. The air pressure utilized may be either low, medium, or high, depending upon the particular design. The pressure-atomizing burners and air-atomizing burners may assume the form of the ordinary gun type and spray the oil and air into the furnace horizontally, or the spray may be directed downward at an angle, vertically upward into the combustion space, or at some other angle depending upon the general effect desired by the designer.

VERTICAL-ROTARY ATOMIZING TYPE

Another general type of atomizing burner is known as the "vertical-rotary" type. In this type of burner, the mechanism is placed entirely or almost entirely inside the base of the boiler and the oil is atomized by being thrown from the rim of a revolving disk or cup. The disk or cup speed in some types is relatively high, and the motion is obtained either by direct or indirect drive from an electric motor.

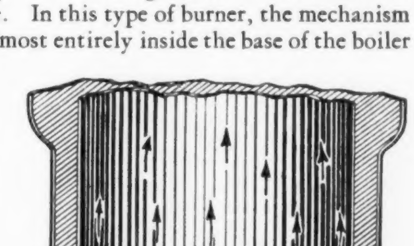


FIG. 3 VERTICAL-ROTARY TYPE OF OIL BURNER

Fig. 3 illustrates a motor-driven centrifugal atomizing burner of the vertical-rotary type. In some variations of the vertical-rotary type the atomization is effected at least partially by the use of air that is supplied for combustion.

Referring to Fig. 3 it is seen that the vertical-rotary atomizing burner is placed entirely within the boiler. In this particular burner the oil passes up through the hollow shaft *e* of the motor *d* and is sprayed at high speed from the atomizing cup *a* mounted on the top of the shaft. Oil is fed to the base of the hollow

shaft by gravity. The air represented by the arrows is brought through the space *c* and passes up to mix with the atomized oil. This mixture is thrown outward and the flame burns with a characteristic yellow appearance. The refractory bowl-shaped chamber *b* serves to improve the combustion.

HORIZONTAL ROTATING-CUP TYPE

Another major subdivision of the atomizing type of burner is the horizontal rotating-cup type. In this case the oil is atomized by being thrown from the inside of a spinning horizontal cup. At the same time a blast of air is directed into the furnace along with the atomized oil. Fig. 4 shows a

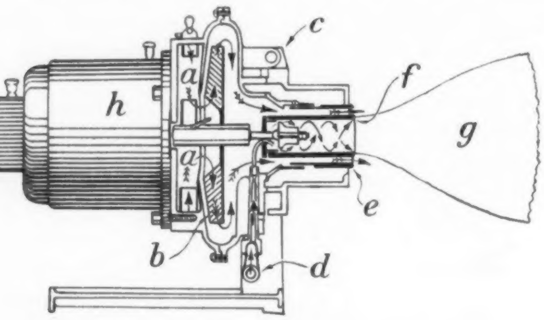


FIG. 4 HORIZONTAL ROTATING-CUP OIL BURNER

cross section of a horizontal rotating-cup burner. Atomizing burners in general, and this holds for the several principal types mentioned, may use the heavier oils so that it is common to find the gun type of burner or vertical-rotary atomizing burner consuming No. 3 and in exceptional cases No. 4 domestic fuels.

THE BLUE-FLAME ROTARY BURNER

One of the most important subdivisions of domestic oil burners and one which deserves to be classified as unique is the vertical-rotary blue-flame burner. This burner has often been designated as a wall-wiping type. The burner functions principally by vaporization, but also at least to some degree by atomization. By reference to Fig. 5 it can be seen that it is of the vertical-rotary type placed entirely within the furnace. The oil is sprayed from the revolving tubes *b* and thrown against the refractory material *d*, metal or clay, which is placed around the combustion-chamber wall, together with the necessary air which is supplied by means of the fan as indicated. The oil is delivered across the hearth *a* in fairly large particles so that the small amount of atomization realized is gotten by impingement on the refractory material around the hearth.

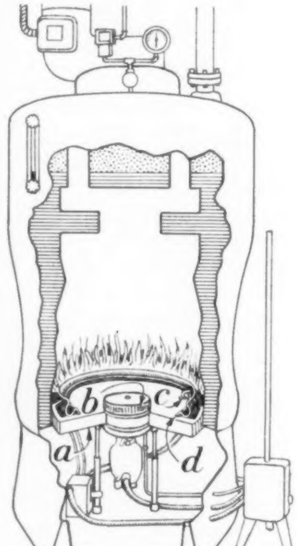


FIG. 5 BLUE-FLAME ROTARY OIL BURNER

After ignition has been established (igniter located at *c*), however, the hearth and the target wall, or flame ring as it is sometimes called, become warmed somewhat, resulting in vaporization of the oil and its premixing with air prior to burning. The resultant combustion in this type of burner produces the so-called blue flame. Actually, however, in practice the most satisfactory type of flame for this class of burner is generally that flame which has a blue base with yellow or orange tips, rather than entirely blue.

This flame is much different in appearance from that produced by the vertical-rotary atomizing burner illustrated in Fig. 3. The flame in the blue-flame wall-wiping rotary is not only different because of its blue color but also because it burns almost directly against the vertical boiler walls and the flame does not begin until the mixture reaches the "target" ring shown in Fig. 5, whereas the flame in the case of the burner shown in Fig. 3 begins just after the mixture leaves the atomizer cup.

COMBUSTION OF OILS

Table 2 summarizes combustion calculations for a typical domestic fuel oil, analysis of which is also given in the table.

TABLE 2 AIR REQUIRED FOR AND PRODUCTS RESULTING FROM COMPLETE COMBUSTION OF OIL WITH NO EXCESS AIR

	Weight, lb per lb of fuel	O_2 required, lb	Air required, lb	Products of combustion, lb: CO_2	O_2	N_2	H_2O	SO_2
C	0.8451	2.256	9.746	3.101	...	7.490	...	...
H_2	0.1298	1.038	4.484	...	...	3.446	1.168	...
O_2	0.0099	−0.010	−0.043	...	...	−0.033[a]	...	...
N_2	0.0099	...	...	...	...	0.010	...	...
S	0.0053	0.005	0.022	...	...	0.017	...	0.010
	1.0000	3.289	14.209	3.101	0.000	10.930	1.168	0.010

[a] N_2 (equivalent) O_2 in fuel.

Therefore the air theoretically required per pound of fuel is equal to 15.209 (total weight of products of combustion) minus 1 (weight of fuel) or 14.209 lb.

From this basic material the absolute and relative weights of the wet and dry products resulting from the combustion of the oil with varying percentages of excess air can be determined by easy means such as are described in any standard handbook on combustion and there is no need to go through such steps in this paper. However, it is perhaps worth while to present, in Table 3, the relative volumes of the dry products, such as would be obtained by the use of the ordinary engineering flue-gas analyzer.

TABLE 3 RELATIVE VOLUMES OF THE DRY PRODUCTS OF COMBUSTION WITH VARYING PERCENTAGES OF EXCESS AIR

Excess of air, per cent	Products of combustion: CO_2, per cent	O_2, per cent	N_2, per cent
0	15.3	0.00	84.7
20	12.6	3.7	83.7
40	10.7	6.2	83.1
60	9.3	8.2	82.5
80	8.3	9.6	82.1
100	7.4	10.8	81.8
150	5.9	12.8	81.3
200	4.9	14.2	80.9
250	4.2	15.2	80.6
300	3.6	15.9	80.5

The relationship between the CO_2 and O_2 is the one of most interest when dealing with the products of complete combustion of the oil. This relationship can be presented most conveniently by means of the Ostwald diagram,[3] Fig. 6. In this diagram the horizontal coordinate is the oxygen content of the flue gas and the vertical coordinate is the CO_2 content of the flue gas, both in percentages by volume. The locus

[3] W. Ostwald, Beitrage zur Graphischen Feuerungstechnik, Leipzig, Monographien zur Feuerungstechnik, Heft. 2, 1920.

of the points of CO_2 and O_2 for the products of combustion with any percentage of excess air forms a straight line connecting the points (CO_2 max, $O_2 = 0$) and ($CO_2 = 0$, $O_2 = 20.9$). CO_2 max is the theoretical maximum value of the carbon dioxide, assuming complete combustion and no excess air. This value depends upon the carbon-hydrogen ratio of the fuel and, for the particular fuel under discussion the value is 15.3 per cent, see Table 3.

This Ostwald diagram was originally devised on the assumption that the only product of incomplete combustion was CO, and various values of CO were represented by lines parallel to the line of complete combustion, and below it. If a given

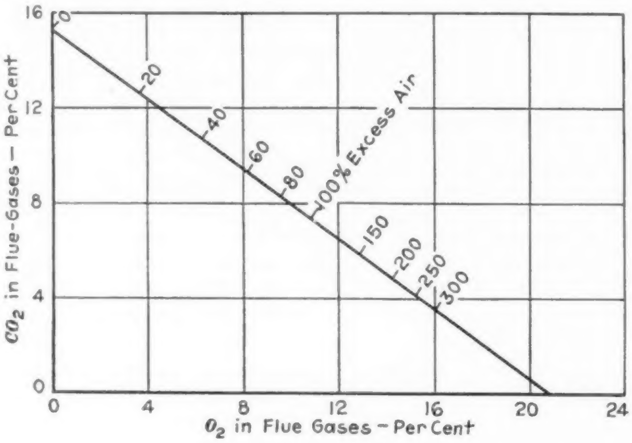


FIG. 6 OSTWALD DIAGRAM

Orsat reading showed percentages of CO_2 below the complete combustion line for a given O reading, it was assumed that incomplete combustion existed and the distance below the complete combustion line represented the amount of CO present. When the products of combustion of the domestic oil burner were studied it was found, on the contrary, that no matter how imperfect the combustion, the point almost invariably fell on the complete combustion line, even when there was a deficiency of air for combustion. Theodorsen developed the theoretical analysis explaining why this should be so, but the steps involved need not be reproduced here.

One of the most interesting incidents of this study was the discovery of considerable unburned gases when the burners were operating under conditions which are generally conceded to give approximately perfect combustion. It has been the general practice to analyze the flue gases by means of the engineering Orsat apparatus which yields the percentages of CO_2, O_2, CO, and by difference, N_2. When this was done and a heat balance made, it was often found that the unaccounted-for losses ran rather high—perhaps as much as 15 per cent of the heat value of the fuel. This would indicate that there must be some unburned gaseous fuel which is not detected by the ordinary flue-gas analyzer.

This unaccounted-for fuel could not be entirely in the form of soot without being readily noticeable and, moreover, it was found that even with a comparatively clear stack this loss was always present to a degree. When the presence of CO was detected at all the amount was only a trace—unless there was an appreciable deficiency in the air supplied.

For a more complete heat balance the flue gases were therefore analyzed by means of the Bureau of Mines gas analyzer, whereby H_2, unsaturated hydrocarbons, and saturated hydrocarbons could be determined in addition to the compounds indicated by the ordinary engineering type of flue-gas analyzer. Table 4 presents test data resulting from the operation of four principal types of domestic oil burners in three cast-iron boilers. The data present the performance at miscellaneous and widely divergent air-fuel ratios and fuel rates, and therefore may not be used to compare the efficiencies of combustion of the various types of burners. The purpose of this table is to compare the results obtained in using the simple engineering gas analyzer with those obtained by using the more complete gas analyzer. The analyses as presented in Table 4 were made after equilibrium had been reached.

If only the simple gas analyzer had been used the values

TABLE 4 COMPLETE HEAT BALANCE

Burner type	Boiler type	Fuel rate, lb per hr	Flue-gas analysis (percentages by volume) CO_2	C_2H_4	O_2	CO	H_2	N_2	CH_4	Excess or deficiency of air (computed per cent) Based on ordinary Orsat	Based on complete analysis	Stack temperature, F
Blue flame												
Vertical-rotary	S-2206	10.4	13.75	0.00	1.25	1.60	0.80	82.05	0.55	− 2.9	− 7.6	455
Vertical-rotary	S-2206	10.4	12.10	0.35	1.35	5.10	0.70	79.80	0.60	−15.5	−21.4	385
Vertical-rotary	S-2206	8.9	12.70	0.00	4.05	0.60	0.35	82.20	0.10	10.8	10.5	430
Gun	W-2004	11.6	9.40	0.00	8.90	0.80	0.60	80.10	0.20	41.7	39.8	638
Retort type	S-2307	8.5	11.00	0.00	6.50	0.10	1.00	81.30	0.10	32.3	30.1	399
Air-atomizing	S-2307	19.5	9.20	0.10	8.20	0.40	0.80	81.30	0.00	53.1	47.8	750
Air-atomizing	S-2307	19.1	12.90	0.40	3.40	0.40	0.50	82.40	0.00	11.8	4.5	740
Air-atomizing	S-2307	19.1	6.90	0.35	11.30	0.50	0.40	80.55	0.00	96.3	79.7	850

Burner type	Useful heat Btu per lb of oil	Per cent of heat value	Incomplete-combustion loss, (per cent of heat value of oil) C_2H_4	CO	H_2	CH_4	Total	Dry stack loss, per cent of heat value	Loss due to combustion of H_2, per cent of heat value	Heat value, Btu per lb of oil	Radiation and unaccounted loss, per cent of heat value Based on ordinary Orsat	Based on complete data
Blue flame												
Vertical-rotary	14230	72.2	0.0	4.4	2.2	4.7	11.3	6.3	6.4	19700	10.7	3.8
Vertical-rotary	11564	58.7	4.1	12.0	1.7	4.4	22.2	4.4	6.1	19700	18.8	8.6
Vertical-rotary	14874	75.5	0.0	2.0	1.2	1.0	4.1	6.9	6.9	19700	8.8	6.6
Gun	13000	66.0	0.0	3.4	2.5	2.6	8.5	13.9	7.1	19700	9.6	4.5
Retort type	14243	72.3	0.0	0.4	3.9	1.2	5.5	7.3	6.3	19700	13.7	8.6
Air-atomizing	11800	61.2	2.3	1.8	3.7	0.0	7.7	17.6	7.3	19300	12.2	6.2
Air-atomizing	13000	67.3	6.3	1.3	1.6	0.0	9.1	12.2	7.4	19300	11.9	4.0
Air-atomizing	9800	50.8	9.6	2.8	2.2	0.0	14.5	24.5	7.2	19300	14.8	3.0

contained under the columns of C_2H_4, H_2, and CH_4 would be lacking. The two columns of percentages of excess air or deficiency show the differences between the computed values of air-fuel ratios when the computations are based on what might be termed the incomplete and the complete analyses. When based on the complete analyses in which practically all the unburned gaseous fuel is included, the air-fuel ratio is less than when based on the relatively incomplete data yielded by the ordinary engineering gas analyzer. The first two runs listed were conducted on a blue-flame vertical-rotary burner with air deficiencies for the purpose of studying the products of incomplete combustion under such conditions.

The percentages of the heat value of the oil represented by the products of incomplete combustion are indicated by that heading. The sum of the losses due to C_2H_4, H_2, and CH_4 which would not be detected by the ordinary gas analyzer are in some instances greater than the loss due to CO in the flue gases, the only product of incomplete combustion which would be detected in the so-called incomplete analysis. The values of the total incomplete-combustion losses are interesting, varying as they do from a low value of 4.1 per cent to a maximum value of 22.2 per cent. It is of interest to note that during the operation of the burner under the latter conditions, when nearly one fourth of the fuel passed up the stack unburned, comparatively little soot was produced. The value of the incomplete-combustion loss in one instance, with considerable air deficiency, was greater than the sum of the dry stack loss and the loss of heat in the moisture resulting from combustion of the H_2 of the fuel. Even when adequate air was supplied, the unburned-fuel loss averaged two thirds of the dry stack loss and usually exceeded the loss in the moisture resulting from combustion of the H_2 of the fuel. The last two columns of Table 4 are interesting in that they indicate a much better accounting for the total heat of the fuel when the heat balance is based on the complete combustion rather than on the incomplete combustion. The average value of the radiation and unaccounted-for loss based on the ordinary gas analyzer for the several runs listed is 12.6 per cent, while based on the complete analysis it is 5.7 per cent. Assuming a radiation loss of 3 per cent in both cases, this would leave net unaccounted-for losses of 9.6 and 2.7 per cent, respectively.

Thus, while the ordinary engineering Orsat apparatus is quite useful and perhaps indispensable in the field adjustment of oil fires, it is obviously not entirely satisfactory when an accurate heat accounting is to be made in precise laboratory work. Since the carbon-monoxide measurement is of relatively little value by itself, it is the belief of the author that the most practicable type of gas analyzer for the oil-burner man who is confronted with the task of making oil-burner adjustments in the field is the single pipette variety utilizing a caustic solution for the absorption of CO_2.

DISCUSSION OF TEST RESULTS

In the following presentation of test results an effort has been made to select the most important illustrative data from an enormous mass of burner-boiler performance records which have been obtained over a number of years. Much more detailed results are presented in the technical publication of the Bureau of Agricultural Engineering, such as Technical Bulletin 109, already mentioned.

In the limited space available performance data will be presented for the following installations: Typical domestic oil burners in several common types of house-heating boilers, originally designed for the use of coal; one of the poorer boilers when fitted with one of the economizers designed to improve the efficiency of such boilers; one of the commonly used types of special oil-burning boilers with a conversion oil burner; and one of the modern special burner-boiler units.

One of the types of coal-burning boilers which will be discussed in connection with the following performance data is the familiar cast-iron round boiler, such as that shown in Fig. 7. This type of boiler is made up in sections consisting of the base, firepot section, one, two, or three intermediate sections, and a dome. If one intermediate section only is used the boiler is referred to as a 4-section boiler, consisting of base, firepot, one intermediate section, and the dome. Similarly, if two intermediate sections are employed the boiler is referred to as a 5-section boiler, and if three intermediate sections are employed the boiler is referred to as a 6-section boiler, which is the maximum ordinarily encountered. The 4-section boiler is the one with the minimum of flue travel or secondary heating surface and the 6-section boiler contains the maximum of secondary heating surface. Since the secondary heating surface is of relatively greater importance with some types of oil burner than it is in the burning of coal, the presence or absence of the intermediate sections makes considerable difference in the efficiency of such boilers when used with oil burners.

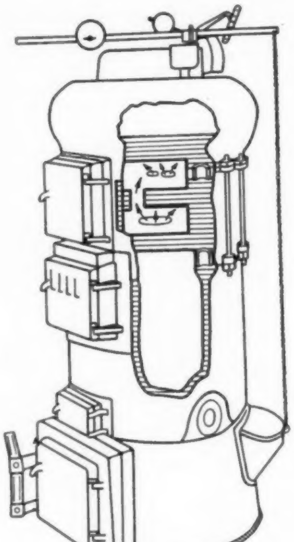


FIG. 7 ROUND CAST-IRON BOILER

The boiler shown in Fig. 8 is referred to by its manufacturer as the water-tube type. Its sections are rectangular and assembled in the vertical plane. Obviously, increasing the number of sections in this type of boiler increases the combustion volume as well as the primary and secondary heating surfaces. Boilers such as these are made in several widths, and in various lengths depending upon the number of sections. The particular boiler of this type used in the Bureau's test was of the 23-in.-wide series and was composed of seven sections.

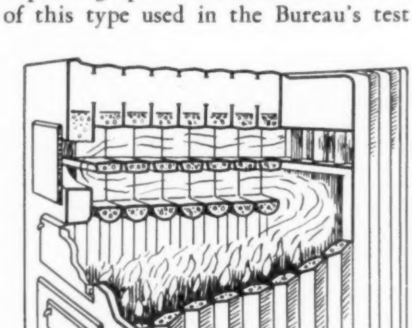


FIG. 8 CAST-IRON WATER-TUBE BOILER

The test results from the operation of one of the most recent cast-iron special oil-burning boilers, a product of one of the leading manufacturers, has also been included in order to afford a comparison between its efficiency and the efficiency of the commoner types of cast-iron boilers, that were originally designed for the burning of coal fuel on a grate.

In order to bring the picture up to date the performance characteristics of one of the most recent models of specially designed boiler-burner units has also been included. The

particular type selected is of steel construction and fired by a pressure-atomizing burner. Both the special cast-iron oil-burning boiler and the steel boiler-burner unit had incorporated in them the coils for domestic water heating.

The performance data of the several pieces of equipment are presented in graph form in Figs. 9, 10, and 12 to 14, inclusive; in each of which the horizontal coordinate is the fuel consumption in gallons per hour and in which the three sets of vertical coordinates are, respectively, thermal efficiency, flue-gas temperature, and output in terms of gross equivalent square feet of steam radiation.

It should be borne in mind that the comparison of test results are on the basis of thermal efficiency only. In selecting a burner for a particular installation the buyer would need to consider other factors, such as type of boiler and amount of service required.

In these tests the control of the burner by automatic devices was omitted, no attempt being made to determine the effectiveness or efficiency of this phase of the burner operation. In general the runs were of several hours' duration. The burner was always operated for a sufficient length of time preceding each test to insure steady conditions before readings were begun. The heat absorption was determined from a knowledge of the temperature rise of a known quantity of water passing through the boiler. Thus the boiler was operated as an ordinary Junker calorimeter. The "efficiency" plotted in Figs. 9, 10, and 12 to 14 may be defined as the ratio of the heat absorbed by the water in the boiler to the heat contained in the fuel supplied. In other words it is the proportion of the heat energy of the fuel which is actually transmitted to the heating medium, which in this case is water.

The output in gross equivalent square feet of steam radiation at any given fuel rate is equal to the fuel rate multiplied by the calorific value of the fuel in Btu per gal, multiplied by the efficiency (expressed as a decimal), and divided by 240, which is the number of Btu emitted in one hour by one square foot of standing cast-iron radiation of the steam type.

It was the purpose in the presentation of the data in Figs. 9, 10, and 12 to 14 to generalize as much as feasible. Accordingly, it was decided to present data for the three most common types of burners, based on the experiences of the author in the answering of hundreds of inquiries yearly. The three most common types are the vertical-rotary type, the gun type, and the so-called retort type. As previously mentioned, the vertical-rotary type of burner may be of the yellow-flame atomizing variety or the so-called blue-flame wall-wiping type. The efficiencies of these two types of burners were found invariably to be so nearly alike in all types of boilers studied by the Bureau of Agricultural Engineering that they have been classed together and referred to merely as the vertical-rotary type when discussed from the standpoint of performance as depicted by the several graphs.

Reference will first be made to Fig. 9, which shows the performance of burners in a 6-section round boiler. The curves for the three types indicate that for this particular boiler the vertical-rotary type shows the highest efficiency and the gun type the lowest, while the efficiency of the retort type lies between these two. Each of the efficiency characteristics is quite flat and either concave downward as in the case of the vertical-rotary and retort types or practically a straight line as in the case of the gun type. (Each of the curves in Figs. 9, 10, and 12 to 14 shows performance for the air-fuel ratios which would prevail in good practice for the several types of burners.) The flue-gas-temperature curves at the constant air-fuel ratios are straight lines over the range of fuel rate shown, and as would be expected they lie in reverse relative positions to the efficiency curves, the gun type showing the highest stack temperature, the vertical-rotary showing the lowest stack temperature, and the retort type lying between the two. The output curves are either straight lines or slightly concave downward depending upon the form of the efficiency curves.

Fig. 10 shows the performance of the three types of burners in one of the types of cast-iron boiler which lends itself poorly

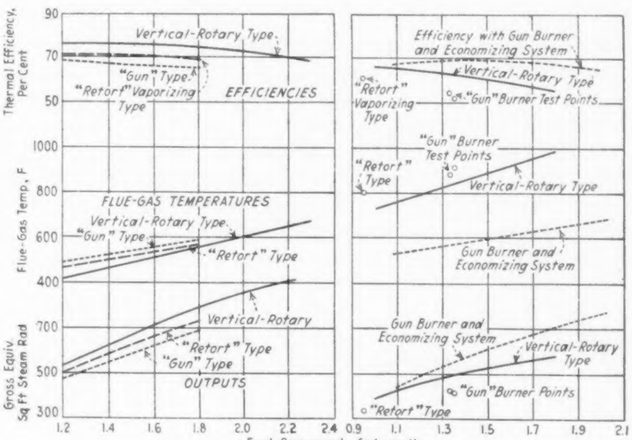


FIG. 9 FIG. 10

FIG. 9 PERFORMANCE OF OIL BURNERS IN A 6-SECTION 22-IN. ROUND BOILER

FIG. 10 PERFORMANCE OF OIL BURNERS IN A 4-SECTION 20-IN. ROUND BOILER

to firing with the ordinary domestic oil burner. By way of contrast, the increased efficiency possibly by the use of an economizing system for such relatively deficient boilers is shown in the graph labeled as performance "with gun burner and economizing system." Only a few individual test points are given for the "retort" vaporizing type and gun burner in Fig. 10.

The type of economizing system used for improving the burner performance can be described by reference to Fig. 11. It consists of two principal parts: (1) A water-containing casting lined with refractory material, thus forming a combustion chamber and at the same time providing additional heat-absorbing surface which is tied in with the boiler by means of piping as shown. This provides what might be termed additional "direct" heating surface. (2) Additional "indirect" heating surface is provided by this manufacturer in the form of "extended" surface as shown in the upper flues. This extended surface takes the shape of fingers of metal which "collect" heat and transmit it to the boiler walls and thence to the water. These components of the economizing system are not connected in any way, and therefore either one or the other may be employed or both, as was the case in the tests reported. Still other types of economizer take the form of water-containing

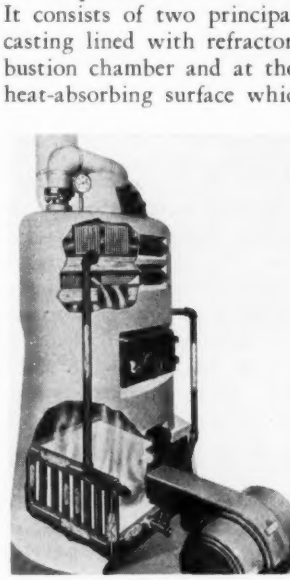


FIG. 11 HEAT-ECONOMIZING SYSTEM USED IN CERTAIN TESTS

TABLE 5 PERFORMANCE SUMMARY

Type of boiler	6-Section round			4-Section round			7-Section water tube			Special: Special oil-burning,	Special: Boiler-burner unit,
Burner	Rotary	Retort	Gun	Rotary	Retort	Gun	Rotary	Retort	Gun	Rotary	Gun
Efficiency, per cent	76	70	66	63	56[a]	54	76	72	72	72	82
Flue-gas temperature, F	520	540	560	850	875[a]	900	490	490	530	650	350
Gross output, sq ft steam radiation	730	700	640	500	475[a]	425	900	850	850	700	620

[a] Estimated from available test data.

castings which are placed in the firebox, but generally above the fire and above the combustion chamber itself. Such devices are also tied in with the boiler in a way that is similar in effect to that already described.

The reduced efficiencies and outputs and markedly increased stack temperatures in Fig. 10 over those in Fig. 9 are apparent, as is the marked improvement due to the addition of the economizing system. (The results will not be discussed in detail at this point, but will be treated later in tabular form which will draw direct comparisons between the several types of equipment under discussion.)

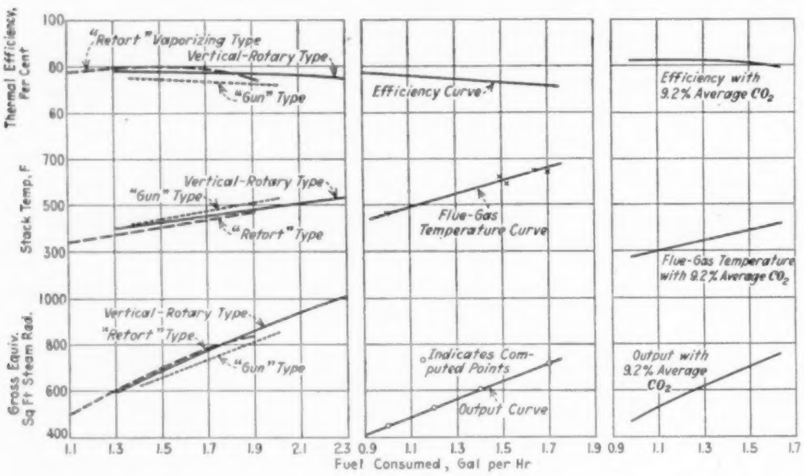


FIG. 12 FIG. 13 FIG. 14

FIG. 12 PERFORMANCE OF OIL BURNERS IN A 7-SECTION 23-IN. WATER-TUBE BOILER

FIG. 13 PERFORMANCE OF A VERTICAL-ROTARY BURNER IN A SPECIAL CAST-IRON OIL-BURNING BOILER

FIG. 14 PERFORMANCE OF A MODERN STEEL BOILER-BURNER UNIT, HAVING GUN TYPE OF BURNER

Fig. 12 shows the performance again of the three principal types of burners, this time in the so-called water-tube type of cast-iron boiler, originally designed for the burning of solid fuel (see Fig. 8). The performances of all of the burners in this unit were better than in either of the two types previously discussed and, in fact, it has been found that the performance of domestic oil burners in the water-tube boiler of adequate capacity approximates that obtained in the best of the units specially designed for the use of oil. There is relatively less difference between the efficiencies of the several types of burners in this boiler than in any other of the many types which the Bureau has investigated.

Fig. 13 has been included to show the nature of the results from a combination of a vertical-rotary burner with one of the most common of the special oil-burning boilers of the present day—one which is used as standard equipment by several burner manufacturers. This efficiency curve is also quite flat. The flue-gas-temperature graph is again a straight line, and the output curve assumes its characteristic form.

The ultimate in present-day boiler-burner performance is probably represented by Fig. 14 which shows the results of the Bureau's study of one of the up-to-date units of this type. Again the respective graphs of efficiency, flue-gas temperature, and output, all plotted against fuel consumption, are similar in form to those of the preceding figures, but it is apparent that the general performance is somewhat better than in the case of the types previously discussed. The efficiency is generally in excess of 80 per cent and the flue-gas temperature at practically all fuel rates is below 400 F, which is about as good as could be desired in practice. It so happens that the boiler-burner unit referred to is of steel construction and employs the so-called "tankless" scheme for the generation of domestic hot water.

Perhaps the most interesting and profitable way to study the results of the operation of the different burners in the various boilers is to tabulate the several performances at those fuel rates at which they would most likely be used. Accordingly, Table 5 is presented.

In this table the performance is tabulated for the respective fuel rates at which the several boilers would probably be fired in everyday practice. The three items, efficiency, stack temperature, and gross output have been selected for comparison. In the two round boilers the vertical-rotary burner shows the highest efficiency, lowest flue-gas temperature, and largest relative output. The retort-type burner lies between the gun burner and vertical-rotary burner in performance.

In boilers of relatively adequate flue travel, such as the 7-section water tube, the difference in performance of the several burners becomes relatively small and the efficiencies of the retort and gun types become approximately equal under ordinary operating conditions. The efficiency of the boiler-burner unit shows what can be done when adequate flue travel is provided for the gun burner, yielding efficiency of 82 per cent and stack temperature of only 350 F. There is apparently a definite trend toward the use of the so-called gun burner in most of the boiler-burner units of today.

Another interesting fact was brought out in connection with the test of the economizing system which has not been included in the tabulation, but which can be seen by reference to Fig. 10. With the economizer and operating at a fuel rate of 1.35 gal per hr, the efficiency becomes 69 per cent as compared with 54 per cent for operation of the gun burner in the plain boiler; the stack temperature is 580 F instead of 900 F; and the gross output is 560 sq ft of steam radiation as contrasted with 425 sq ft. The use of such an economizing device should result in practice in the saving of approximately 25 per cent of the fuel otherwise required to do a given heating job.

(*Continued on page 728*)

QUIETING MACHINERY

Analysis of Actual Problems Solved and Fundamentals Involved in Each Problem

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THIS PAPER is the result of a request for material on practical means for quieting machinery. Unfortunately, such problems and their solutions are marked by their differences rather than their similarities. It is quite easy to write in general terms about the characteristics of hearing and the advantages and disadvantages of sound meters (1, 2, 3).[1] Also, it is a fairly straightforward matter to describe any particular instance of quieting. Valuable as such material might be, it was felt that it could hardly give an adequate idea of the great variety of factors encountered in practical noise problems, and the extreme flexibility and power of acoustical measurements in dealing with them.

In reviewing the noise problems with which the author has come in contact during the past decade, it was found that each involved different controlling factors, and each required a different technique of attack. This paper consists of a brief outline of 12 of these problems. Each example is quite complete in itself; the particular problem is stated, the important factors mentioned, the method of attack indicated, and the results outlined.

While these individual accounts are interesting in themselves, the principal purpose of the paper is to present their effect as a whole. Each example was selected because it illustrates differences in aim, controlling factors, point of attack, technique of measurement, type of result, or method of correction. At the end of each example are listed some of the fundamentals illustrated therein. While this list of problems is by no means complete, it is believed to be quite representative. Certainly, it well illustrates the variety and complexity of everyday noise problems, and how even the most difficult ones can be solved effectively with the aid of instrumental measurements.

SIMULTANEOUS TREATMENT OF ALL PROMINENT NOISE SOURCES IS IMPORTANT

Fig. 1 indicates a noise problem. Oil was fed to a storage tank by a gear pump which produced an annoying note of about 700 cycles. The noise appeared to come from the tank, and the owner thought that it must be telegraphed through the pipe. Accordingly, he placed a flexible section in the pipe, but the noise seemed just as loud as before and so the flexible section was removed. The next idea was that the noise was caused by pressure surges, and a side tube was installed to absorb them. The outfit was still as noisy as ever, and the owner looked for help on this problem which did not seem to make sense.

The problem was easily and effectively solved by installing a flexible section and a surge absorber simultaneously, and thus reducing both sources of noise at the same time. This demonstrated the oft-encountered fact that if there are two or three noises of about equal prominence, little benefit is gained from reducing only one of them.

Fundamentals:

1 For practical purposes, one source of sound was nearly as loud as two.

2 The original source of sound was not the surface from which it was radiated, and isolation was very effective.

This was a simple job, and easily solved without much measurement. The one described next was more complicated.

QUIETING OF ELECTRICAL SUBSTATION

Fig. 2 shows a residential substation which it was desired to quiet (4). Measurements were taken in the neighborhood to determine which pieces of equipment were responsible for the noise, and how they could be quieted. Frequency analyses showed that the sound consisted of musical notes. Unpitched sound was negligible. The notes were harmonics of 120 cycles, i.e., 120, 240, 360, 480, etc.

It was not feasible to make sound-level (total noise) measurements at any considerable distance from the station because of extraneous noise from traffic and other sources. Frequency analysis of individual notes allowed the station noise to be separated from the extraneous noise, but increased the number of readings required. Most of the readings were made on the 120-cycle note, as this was usually the most prominent. Under some conditions, harmonics as high as 1000 cycles were prominent.

Wave patterns were large so that it was necessary to average a number of readings to obtain usable ratings. Fig. 3 shows how the level of the 120-cycle note varied as one moved directly away from the station. Readings were taken at 3-ft intervals. Station 1 was about 10 ft from the large transformers in the back yard of the station, and station 53 was on the far side of the adjacent street nearly 160 ft farther from the transformers. While in general it was quieter at greater distances, it is interesting to note that the reading at the first station (10 ft from the source) is exactly the same as that at the next-to-last station more than 150 ft distant. These patterns were caused by interference of the various waves of sound, and are almost invariably encountered in machinery noise work.

Fig. 4 shows the results of a quieting experiment. Readings were taken along a line 150 ft distant from the transformers to determine their relative importance as noise sources. The full line shows readings taken with both transformers in operation, and the dotted line readings with one of the transformers shut down. Surprisingly enough, there are a number of stations at which the level is from 5 to 20 db louder when only one unit is in operation. However, there are other stations at which the reverse is true. The average values are the same within a decibel, indicating that the transformer which was shut down is considerably quieter than the remaining one.

[1] Numbers in parentheses refer to references at end of paper.

Prepared in connection with a Demonstration Lecture on Quieting Machinery, to be presented at the Annual Meeting, New York, N. Y., Nov. 30 to Dec. 4, 1936, of The American Society of Mechanical Engineers.

This was checked by taking measurements with the other transformer operating alone. Under this condition the level was reduced about 20 db.

Measurements of this type showed that in order to obtain appreciable reduction in noise, it was necessary to quiet the noisy transformer, and also to reduce the noise from the voltage regulators inside the station. The transformer was replaced by another which had means for keeping the internal vibrations from reaching the outer shell where they were radiated. The ventilating louvers for the regulators were closed with steel plates, and ventilation provided by drawing air from the basement of the station. Experiments were made with various sorts of partitions in place of the exterior doors to the regulator rooms, but it was found that the sound levels outside were not determined by sound passing these areas, and the simple use of steel plates in place of the louvers gave as much quieting as the most expensive and complicated partition that could be built in these openings.

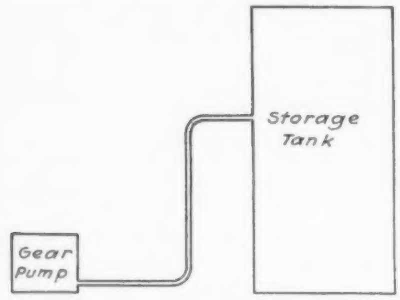

FIG. 1 NOISE FROM TANK INVOLVED TWO TYPES OF SOUND TRANSMISSION

Table 1 shows the overall effects of the quieting moves made.

TABLE 1 LOUDNESS LEVEL OF 120-CYCLE NOTE, DECIBELS

	—Loudness level, db—		
Location	Before	After	Reduction
Across street in front of station	57	21	36
In alley at rear of station	60	46	41
Adjacent street behind station	51	20	31

As soon as these changes were made, complaints from noise in this location immediately ceased.

Fundamentals:

1 In this case the noise was important only on neighboring property at considerable distances from the source.

2 While the analyzing ability of the human ear made it possible to hear the noise from the station, measurements showed that at most locations the total sound level was usually determined by other noises (from traffic, etc.).

3 With a sound-level (total noise) meter, it was impossible to separate the station noise from the other noises, and hence such readings were of little value at distances of practical interest.

4 Frequency analysis of individual components of the noise allowed the necessary separation to be made, but increased the number of measurements required.

5 The sound from this station consisted almost entirely of musical components so that "unpitched sound" was negligible.

6 Due to differences in level, and the characteristics of human hearing, the relative importance of the component notes was not the same close to the station as it was at more distant points.

7 Wave patterns were very large. By ear it was difficult to average out these effects to determine overall effects, but it was easily done by meter.

8 Changes in the noise sources produced large changes in wave pattern, so that observations at individual locations were of no value in determining the overall effect of the change.

9 Simple measurements showed that the controlling noise did not pass through the doors to the regulator rooms. Hence, expensive partitions which had been considered for these areas would have been a useless expense.

10 The importance of the various sources of noise having been determined, effective quieting measures were designed, and a marked quieting achieved at moderate cost.

NOISE INSPECTION ON PRODUCTION

The third example differs from the two already cited in that it was concerned primarily with production rather than individual installations. A manufacturer of cream separators had encountered difficulty in obtaining consistent noise inspection of his product and in determining which parts of the mechanism should be changed on rejected units.

Frequency analyses of the noise of a selected group of noisy machines were made in the laboratory. It was found that the various machines produced different acoustical spectra, and that in each instance it was possible to relate the important sound components with part of the machine responsible for the particular noise.

On the basis of this investigation it was decided that suitable inspection and diagnosis of noise could be made by making three separate measurements on each machine. A special-purpose meter was provided to make these three readings in the plant on production. A necessary part of this setup was a special stroboscopic speed indicator so that speeds could be held to closer limits for analysis. This installation has been in use for several years with excellent results (5).

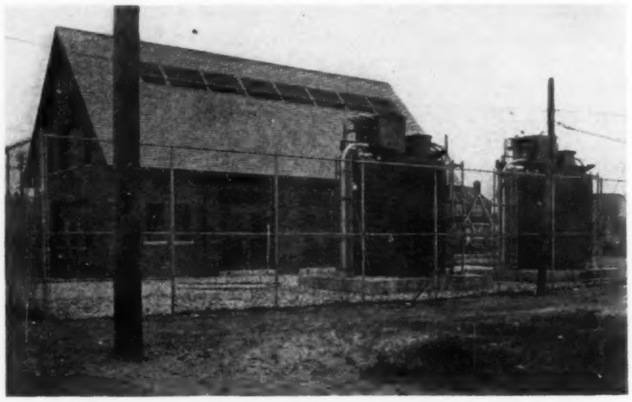

FIG. 2 RESIDENTIAL SUBSTATION

Fundamentals:

1 Noisy machines were caused by several independent factors, any or all of which might be important on a given unit.

2 Frequency analysis of these noises in the laboratory made it possible to determine which parts were responsible for each of the important noises.

3 These data showed what measurements were needed on production. Many attempts to use meters for inspection have been unsatisfactory because such analyses were not made.

4 A practical inspection instrument was provided on the basis of the noises found to be important in actual machines.

LOCATION OF OBSCURE CAUSES OF NOISE

In the previously described problems, the sources of the noise were fairly obvious; the problem was primarily a matter of determining their relative importance, and how they could best be handled. It often happens that the actual cause of the noise is obscure, and experimentation can be almost endless. The following example indicates how acoustical measurements can be used to advantage in such cases.

A manufacturer encountered difficulty with noise in his

product. As is so often the case, it seemed almost impossible to locate the cause. Many of the machines were satisfactory but others were noisy. Most careful checks of limits and tolerances showed no differences between the noisy and the quiet units. Units made with especially close tolerances were often noisier than average. Assemblies made from the parts of previously rejected machines were often quiet. This just did not make sense.

After making various acoustical measurements and analyses, the run shown in the upper curve of Fig. 5 was made. The machine was operated by an ordinary induction motor, which operated at essentially constant speed. To determine the effects of moderate changes of speed, the frequency of the power source was varied. As shown in the upper curve, a slight reduction in frequency (speed) increased the noise nearly 15 db. This increase was easily traced to resonance in a vibration isolator which formed part of the machine. Herein lay the explanation of the trouble. On some machines, differences in weight of castings and stiffness were sufficient to bring the operating condition up on the side of this curve; on others, the operating speed would come near the minimum. Different

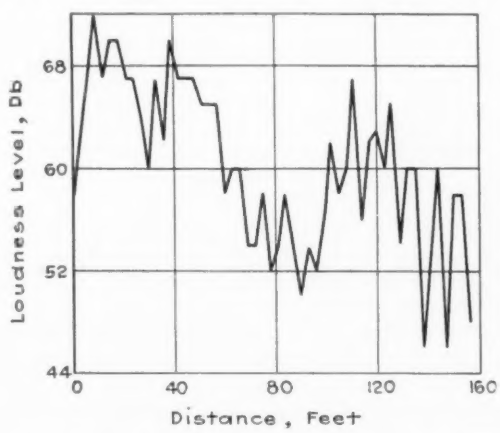

FIG. 3 NOISE LEVEL (120-CYCLE NOTE) DOES NOT DIMINISH STEADILY AS DISTANCE FROM STATION IS INCREASED ON ACCOUNT OF SOUND-WAVE INTERFERENCE

(Distances were measured from a point on the fence midway between the transformers in Fig. 2.)

assemblies of the parts might shift the critical frequency for better or worse.

Practical quieting often is obtained by removing material, and lessening cost of production rather than adding additional material to a noisy machine and increasing cost. Acting on this theory, part of the resilient material in the isolator was removed, with the results shown in the lower curve of Fig. 5. Not only was the peak eliminated so that production variations produced no effect on the noise, but the level was also lowered. This quieting was accompanied by a small decrease in cost of production.

Fundamentals:

1 This was primarily a question of diagnosis. Sound measurements are very effective in this role.

2 The corrective was quite obvious once the cause was determined, and involved no increase in production cost.

3 Most problems seem simple once they are understood, and acoustical measurements enable the explanations to be obtained quickly.

REAR-AXLE GEAR NOISE—A COMPLICATED PROBLEM

For purposes of exposition, the problems already outlined are good because they are explicit. Unfortunately, many practical problems are not so simple but involve a number of factors and ramifications. One of the most valuable uses of sound measurements is in untangling such complications and reducing them to understandable information; usually in the form of numerical data. Accordingly, it seems advisable to include one such example, even though it involves difficulties of presentation. In the space available, only some of the factors and results can be outlined. The purpose in presenting the material is to indicate the type of work rather than to write a compendium on gear noise.

Some years ago a client became interested in the possibilities of an instrumental noise inspection of automobile rear-axle

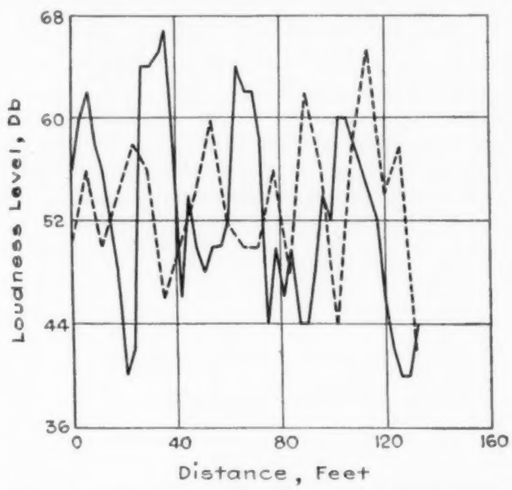

FIG. 4 EFFECT OF CHANGE OF SOUND SOURCES ON LEVEL OF 120-CYCLE NOTE

(Solid line, with both transformers in operation; dash line, only one transformer in operation.)

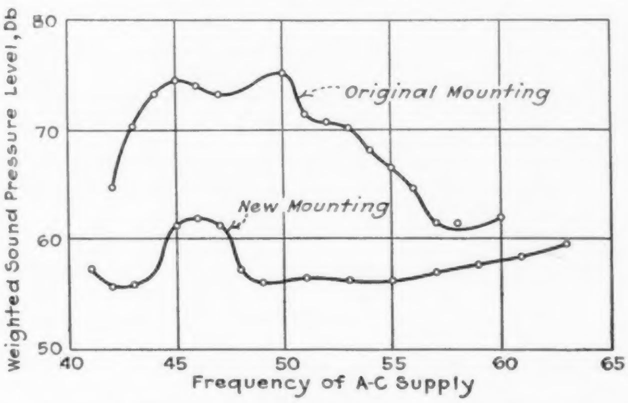

FIG. 5 TESTS SHOWING INFLUENCE OF SMALL SPEED CHANGES ON NOISE

(Quieting was obtained by minor change in a vibration isolator on the machine.)

gears. Measurements showed that this sound consists principally of a series of notes whose frequencies are multiples of the frequency of tooth contact. For example, a set of gears with an 11-tooth pinion operating at 1200 rpm has $1200 \times 11/60 = 220$ tooth contacts per second. Notes of 220, 440, 660, 880, etc., cycles per second result. These notes are identified as the first, second, third, etc. harmonics of tooth-contact frequency.

While harmonics as high as the tenth or twelfth (2200 to 2640 cycles) were present, it was found that on most gears, those

above the fourth were negligible compared with the others. It also was found that the relative importance of the various component notes was different for different gear sets. See Fig. 6. This accounted for the individual character of the noise of various gear sets.

Tests were made with a sound-level meter, which measured all components of the sound simultaneously, thus giving a single reading. Comparison of meter readings with the ear ratings of an experienced inspector showed approximately the following results:

Agreement between inspector and meter,	75 per cent
Passed by inspector, rejected by meter,	$12^1/_2$ per cent
Rejected by inspector, passed by meter,	$12^1/_2$ per cent

Obviously, the inspector and the meter were listening for different characteristics of the sound.

There was reason to believe that the inspector had some basis for his judgment because he had listened to many axles which had been rejected by customers. The problem was to interpret this experience in terms of the acoustical spectrum of the gear noise. In the course of this study an incident occurred

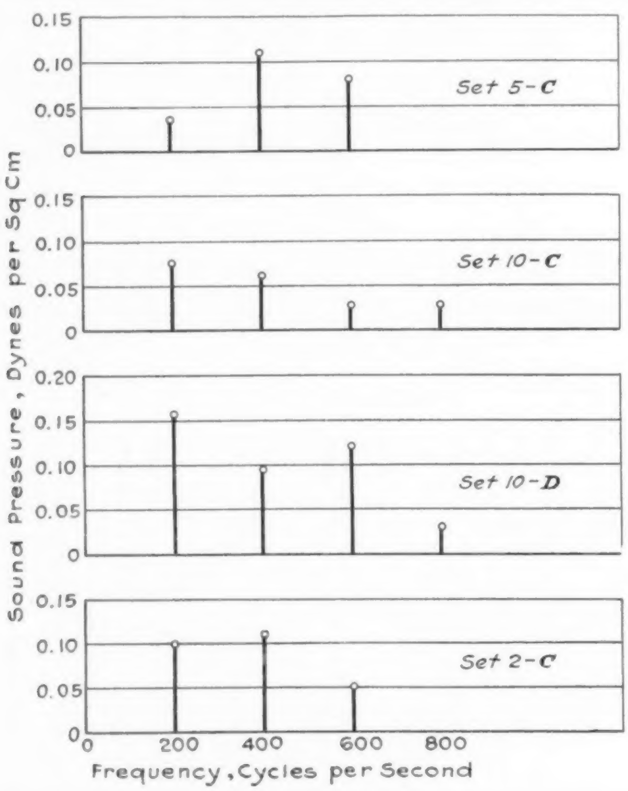

FIG. 6 FREQUENCY ANALYSES OF PROMINENT NOTES FROM FOUR DIFFERENT SETS OF REAR-AXLE GEARS

(Note differences in relative importance of notes.)

which illustrates some of the personal factors of noise reduction.

Sound-measuring equipment was temporarily set up in one of the test booths used for production-noise test. The regular inspector made his usual tests by ear, and I made measurements and listened to determine the correlation. Soon there was a gear which gave a low reading and sounded quiet to me. The inspector said, "Noisy." I inquired if he did not mean that the particular sound was objectionable in the car, even though it was not very loud. Said he, "It sounds noisy to me. Let it go through if you wish. The final inspector will also find it noisy." Later, there was a gear which sounded loud to me and gave a large reading. The inspector said, "O.K." I tried to get him to say that it was quite loud, but of a character that they had found would be satisfactory in the car. Said he, "You can call it noisy if you wish, it sounds quiet to me."

Frequency analysis of the different notes soon showed that the inspector objected particularly to the second-harmonic note. For a given level of sound, gears with prominent first harmonics would be passed, and those with prominent second

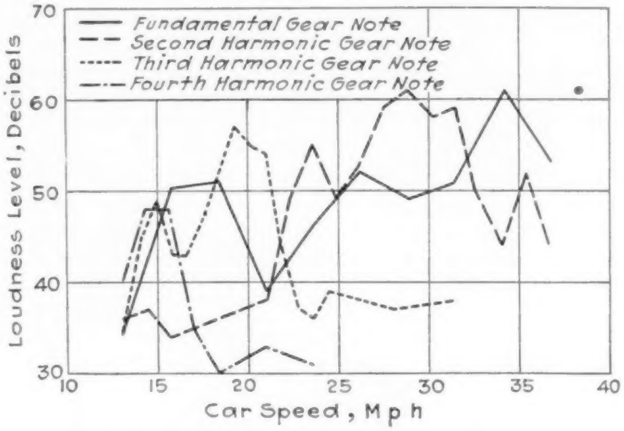

FIG. 7 SPEED-LOUDNESS OF IMPORTANT REAR-AXLE GEAR NOTES IN AN AUTOMOBILE

harmonics would be rejected. It appeared that his rating was based largely on the quality of the sound, second harmonic being particularly objectionable. Was second harmonic especially important in the car?

To answer this question, measurements were made in a car. Fig. 7 shows the measurements obtained at one of the measurement stations. Four component notes (first to fourth harmonics) were measured, and the following information obtained:

(*a*) The level of the sound did not increase steadily with the speed. Instead, the curves show large peaks and valleys (10 db or more).

(*b*) Each of the notes increased until a maximum value was reached, after which it fell quite abruptly and never rose high again. Usually, it was the most prominent note of all at its peak value. The speeds corresponding to these peak values on the graphs are approximately:

4th harmonic................	15 mph
3rd harmonic................	20 mph
2nd harmonic................	30 mph
1st harmonic..........above	40 mph

Readings taken at other measurement stations showed quite different curves, showing that there were at least two important causes of the observed peaks and valleys in the curves. Wave pattern was one of the chief factors. Measurements on a single note at a given speed showed variations in level as much as 20 db from point to point in the car. See Fig. 8. Each note showed a different wave pattern, and with each change of speed, all the patterns shifted entirely.

With observations at one point, it is impossible to tell either by ear or by meter whether a "peak of noise" at some speed is due to a shift of wave pattern or to an actual increase in the average level of the sound in the car. By suitable measurements the wave patterns can be averaged out and true critical speeds determined. Often, the importance of wave patterns

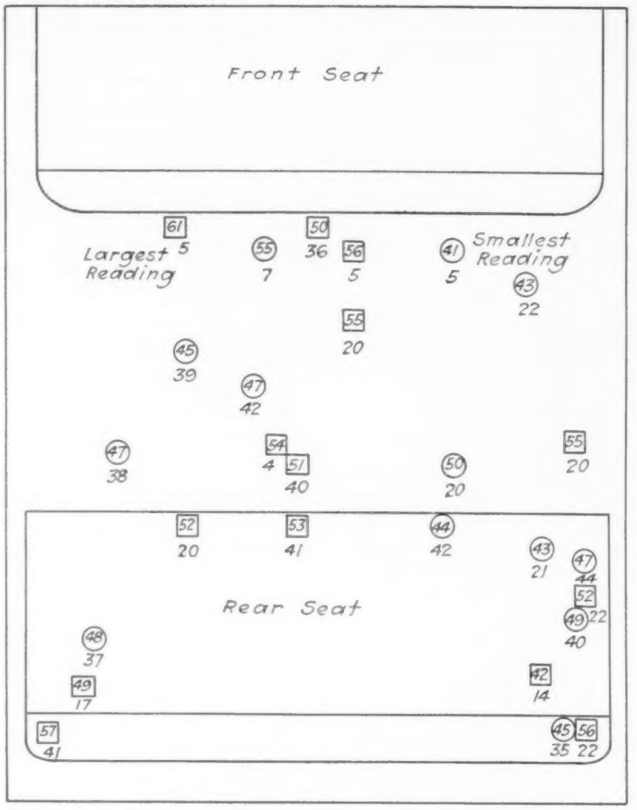

FIG. 8 WAVE PATTERN OF A GEAR NOTE IN A CAR AT A GIVEN SPEED

(Measurements show maximum and minimum levels, and locations where they were obtained.
"Maximum" readings (i.e., louder than nearby points) are enclosed in squares.
"Minimum" readings (i.e., quieter than nearby points) are enclosed in circles.
Enclosed values give loudness level of note in decibels. Small figures below readings give height of measurement station above car floor in inches.)

in practical work is not sufficiently realized. Measurements indicate that a great deal of time and expense have been spent in trying to eliminate "critical speeds" for noise, which were simply peaks in wave pattern at certain points of observation. At other equally important points of observation the sound might be the same as for adjacent speeds, or even show a dip instead of a peak.

Measurements similar to those of Fig. 7 were taken at other stations, and by comparison it was found that the large critical peaks listed in point *b* were obtained generally in the car. Since the speed at which a given harmonic reaches a given frequency varies inversely with the number of the harmonic, these results were simply explained. It appeared that the car had a critical cutoff frequency. Each note increased in level until that frequency was reached, and then dropped off rapidly.

At that time, little difficulty was encountered from gear noise in cars below 25 mph. Since the third and fourth harmonic notes were important only below this speed, it appeared that they could be eliminated from consideration. The most serious trouble with noise was encountered in the neighborhood of 27–32 mph. Since the second harmonic was 5 to 10 db above the other notes in this speed range, it was quite certain that this note was responsible for the noise. This checked the noise inspector's objection to gears with strong second harmonic notes. On the basis of these data, it appeared that first harmonic would be important at speeds above 40 mph, and would reach a peak at about 60 mph. This was above ordinary road speeds at that time (1927) but it appeared that both the second harmonic and fundamental should be measured. Since they "sang solos" at different speeds, it appeared advisable to hold separate limits on each. This was done by providing a special-purpose analyzing sound meter so that the two notes could be measured simultaneously on the stands.

When measurements were made on the test stands, there was no sign of the high-frequency cutoff. See Fig. 9. Instead, each note increased with speed to the highest speeds (with due allowance for wave pattern). Also it was found that the third and fourth harmonics were very prominent on the test stands, although the work just outlined had shown them to be of negligible importance in the car. In fact, on one of the stands used for testing final assemblies it was found that no first or second harmonics could be heard. Instead, they were entirely obscured by third and fourth harmonic notes. Thus the inspector was expected to judge the gears under conditions where the noises that were important in the car could not be heard at all. The only sounds produced were components which were never of importance in the car. This was valuable

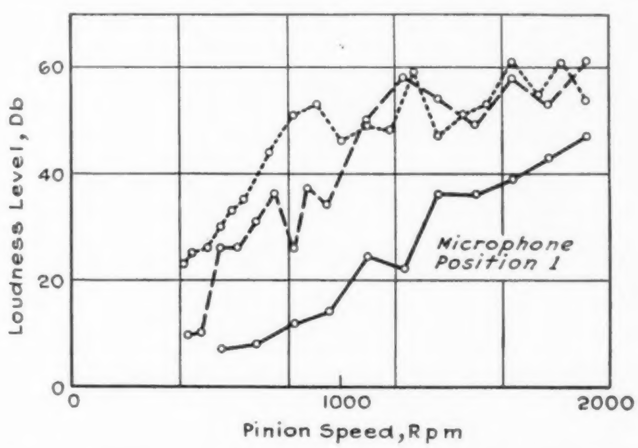

FIG. 9 SPEED-NOISE CURVES OF GEAR NOTES ON TEST STAND

(Note that higher components did not fall off at higher speeds as in the car. Speed range approximately same as in Fig. 7.)

information, and easily obtained by measurements, but it would hardly be possible to find it out by ear. No wonder the inspection was inconsistent with car results!

In the course of this investigation, measurements were made of the paths by which the axle noise reached the interior of the car. It was found that about half the sound came directly through the floor of the car, and about half was transmitted as vibration through the axle, springs, and frame to the body of the car from which it was radiated to the interior. A negligible amount passed up the propeller shaft. Present-day cars have metal floors covered with insulation instead of the wooden floors with wide cracks and meager insulation of that time. Hence this path has been effectively reduced. Most cars still have essentially the same type of rear-spring suspension, and hence gear noise still enters by this path.

Fundamentals:

1 Sound-level (total noise) readings did *not* give a proper rating of the gears because certain parts of the sound (e.g., the second harmonic note) were unusually important.

2 Frequency analysis of the sound into its component notes was required on this problem.

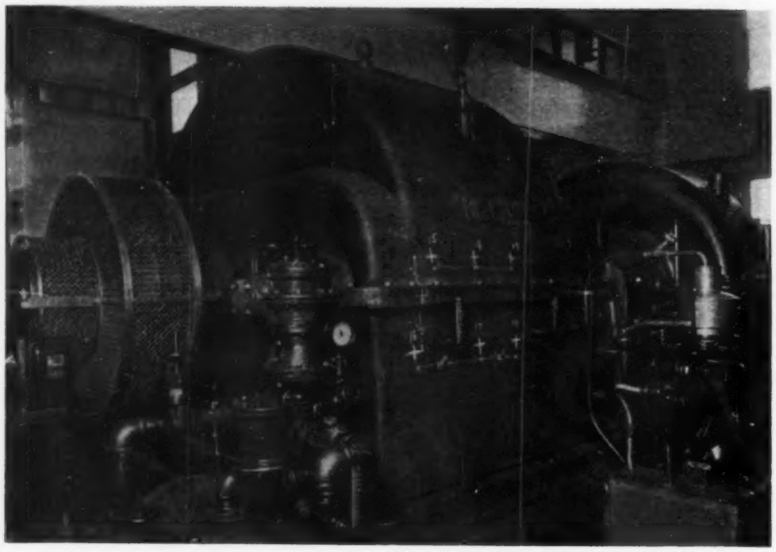

FIG. 10 REDUCTION GEAR USED ON TURBOGENERATOR

3 Peculiarities in the inspector's ear judgments were correctly based on results in the final application, and could be defined in terms of acoustical measurements.

4 Supposedly identical sets of gears showed very different acoustical spectra, indicating several causes of noise.

5 Wave patterns in a typical automobile result in large point-to-point variations in level which are sufficient to obscure critical speeds of noise.

6 Components of sound which were very prominent on the test stand were of negligible importance in the car due to peculiarities in its acoustical response.

7 On one of the test stands, the construction was such that it was impossible to hear component notes which were of primary importance in the car. The only audible sounds were components which car measurements showed were negligible.

8 In the car, it usually happened that one component of the noise was outstanding in a given speed range, while other components were important in other ranges. This indicated that more than one figure would be required for a satisfactory noise rating.

9 The gear noise reaching the occupants of the car traveled by at least two paths of about equal importance. Consequently, little practical effect could be obtained by simply treating the floor of the car.

"OBVIOUS" SOURCE NOT ACTUAL SOURCE OF NOISE

Mention has been made of a problem in which the cause of the noise was obscure. The present example deals with a case in which the source of the noise was apparently obvious, but in which the solution lay in quite a different direction.

A manufacturer of domestic refrigerators had trouble with motor noise. In fact, the trouble was so serious that he paid a premium for motors especially selected for quietness. The motor manufacturer could not understand why he had so much trouble with this particular customer; the refrigerator in question was no quieter than those which used the same motor successfully. Aid was sought.

Frequency analyses were made of the noise of the unit to determine which sounds were most prominent and which parts were responsible for them. (Often the noise is not caused by the part from which it is radiated and which apparently is the source.) As anticipated, motor notes were prominent; not rotational frequency or 120-cycle hum as might be expected, but higher-pitched notes of medium frequency range.

These notes seemed unusually loud, so the motor was removed from the unit and tested separately. It was very quiet. Next it was loaded by means of a small generator, but the increase of noise was slight. Next the fan was used, and up jumped the noise. It looked like the fan, and accordingly the fan was mounted on a shaft and run separately. The fan was also very quiet. These facts led directly to the solution. The fan had certain critical frequencies which were close to some of the motor notes, and acted as a loud speaker for them. Slight changes were made in the shape of the fan which had no effect on its size, weight, efficiency, or cost, but which did shift its critical frequencies away from existing vibrational components. Almost any motor could be used with this new fan, and the company stopped paying the premium for selected motors. Thus quieting was accompanied by a decrease in the cost of production.

Fundamentals:

1 The fundamental cause of the noise was not in the part to which it had been attributed, and on which work had been done.

2 Frequency analysis enabled the important notes to be identified and worked upon in the presence of other noise.

3 Instrumental measurements of sound allowed comparisons to be made of setups made at different times and to determine whether the various components of the noise added to give the expected totals. The problem was solved because of discrepancies in such additions.

4 The quieting was achieved at no increase in cost of the offending part and with a decrease in cost of associated parts.

DIAGNOSING FUNDAMENTAL CAUSES OF NOISE FROM SOUND MEASUREMENTS

It often happens that acoustical measurements yield unexpected but very definite information concerning the mechanism of a machine and indicate where improvements may be made to advantage. Fig. 10 shows a large reduction gear on which this was done (6).

The initial purpose of the work was to determine noise specifications for this type of unit so that a central-station company could include them in the order for their next turbogenerator unit. While such specifications are entirely feasible, it is desirable to determine them on the basis of existing equipment rather than to write them entirely on the basis of personal opinion. To this end, both sound-level measurements and frequency analyses were made on a group of existing units. Typical frequency analyses are shown in Fig. 11.

These measurements showed that the machines had very prominent musical components. These notes were all harmonics of two fundamental frequencies. Surprisingly enough, these fundamental frequencies did not correspond to frequencies of tooth contact as in the case of the automobile gears, but instead were related to frequencies of rotation. Each of these gear units consisted of a large bull gear meshing with two separately driven pinions. The two series of notes were harmonics of speeds of these pinions. No notes could be detected which corresponded to bull-gear rotation. Each different gear set showed an entirely different acoustical spectrum (although all notes were harmonics of pinion rotation). When one of the sets was reconditioned by taking a small cut from the working side of the teeth, the acoustical spectrum was entirely different from what it was before. From these observations the following conclusions follow:

(*a*) Errors in tooth contour were not responsible for the noise. (Tooth-contact frequency was missing or negligible in this case.)

(*b*) Misalignment or deflection under load was not re-

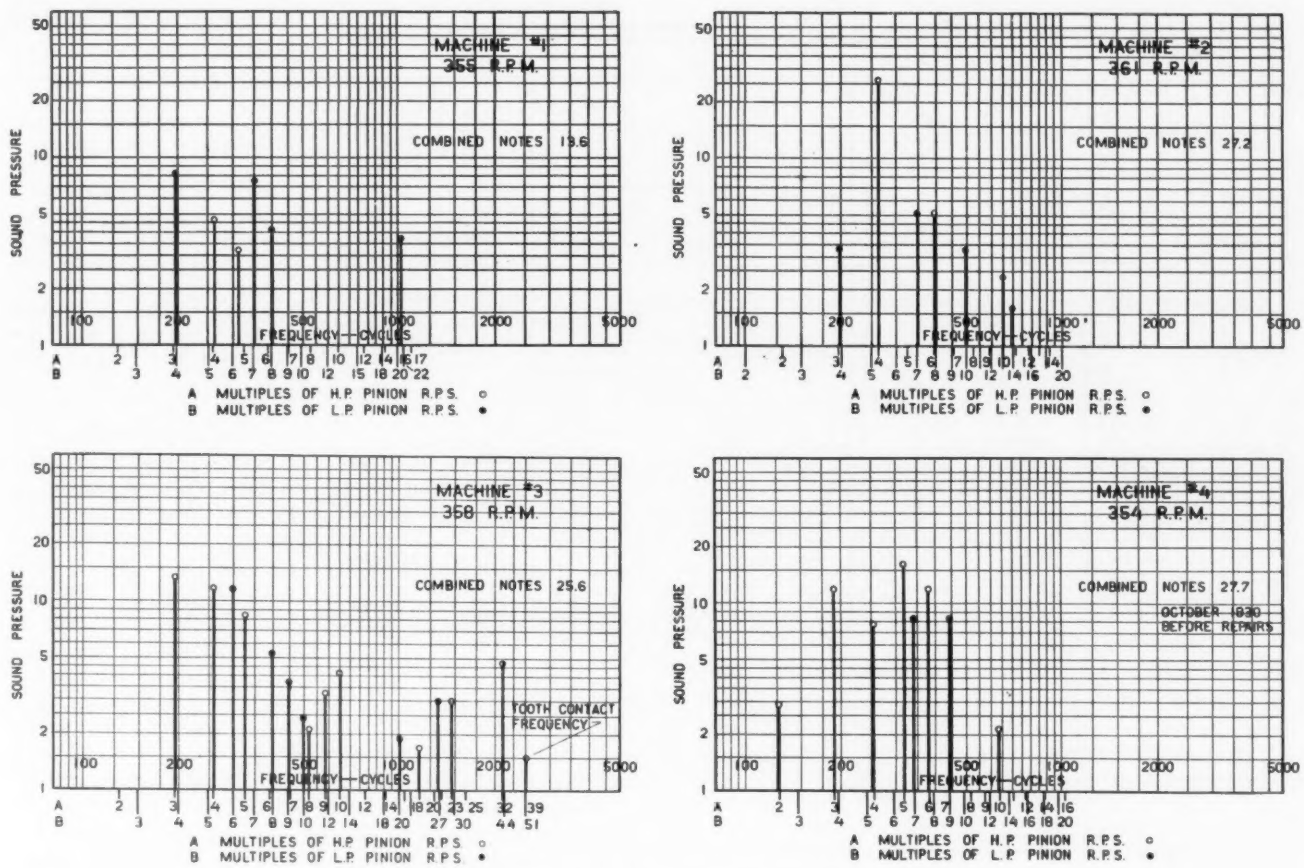

FIG. 11 TYPICAL FREQUENCY ANALYSES OF GEAR UNITS

(Note differences in number, pitch, and relative importance of components.)

sponsible for noise. (These would produce tooth-contact frequency.)

(*c*) Imperfect balance was not responsible for noise. (Fundamental rotational frequencies were missing.)

(*d*) The pinions were responsible for the noise, not the gear.

(*e*) The particular pinion responsible for each note was obvious.

(*f*) Notes were not caused by resonances of the shafts, webs, casings, etc. (Units with closely similar parts gave very different spectra. Even the same unit gave a different spectrum when the tooth surfaces were refinished.)

(*g*) This information indicated quite clearly that the errors causing the noise were produced by the machine on which the gears were cut, particularly the machine used in cutting the pinions. Further, the errors were not in the form of the cutter, but in the mechanism by which the blank was indexed from one tooth to the next, and by which the tooth spiral was generated.

In addition to the musical components just described, measurements showed that "unpitched sound" was prominent on several of the gear units. The reconditioned unit showed materially less unpitched noise than the others, indicating that roughness of the teeth was an important cause. Unevenly spaced irregularities on the bull-gear and other surfaces would also produce this type of noise.

Fundamentals:

1 Acoustical measurements yielded unexpected and valuable information concerning machinery mechanism.

2 The foregoing conclusions listed provide a definite diagnosis of the fundamental causes of the noise.

3 Noise specifications for such machinery appear entirely feasible.

EVIDENCE IN COURT TESTIMONY

Not only are measurements of sound valuable in carrying out quieting programs, but they can be used to settle questions of fact concerning noise levels.

Recently a drop-forge plant was sued for producing excessive noise and vibration in the neighborhood. This plant was a small one located in an industrial subdivision and did not operate at night. The nearest house was a block and a half distant.

Measurements made adjacent to the property of several of the complainants showed that by careful listening, the hammers could be heard during lulls in the general noise level. However, the hammer noise was completely obscured by ordinary noises such as passing automobiles, nearby trains, children playing, dogs barking, doors slamming, etc. Since there was hardly a minute during the day when there was not one or more of these ordinary noises, it appeared that the plant contributed little to the noise of the neighborhood. Fig. 12 shows typical measurements made and used as evidence. The case was decided in favor of the defendant.

Although a favorable decision was received in this instance, the company recognizes the trend toward the reduction of city noise and is working on quieting means. Work is now in progress to determine the various paths by which sound is emitted by the plant, the relative importance of these paths, and the most economical methods of obtaining quieting.

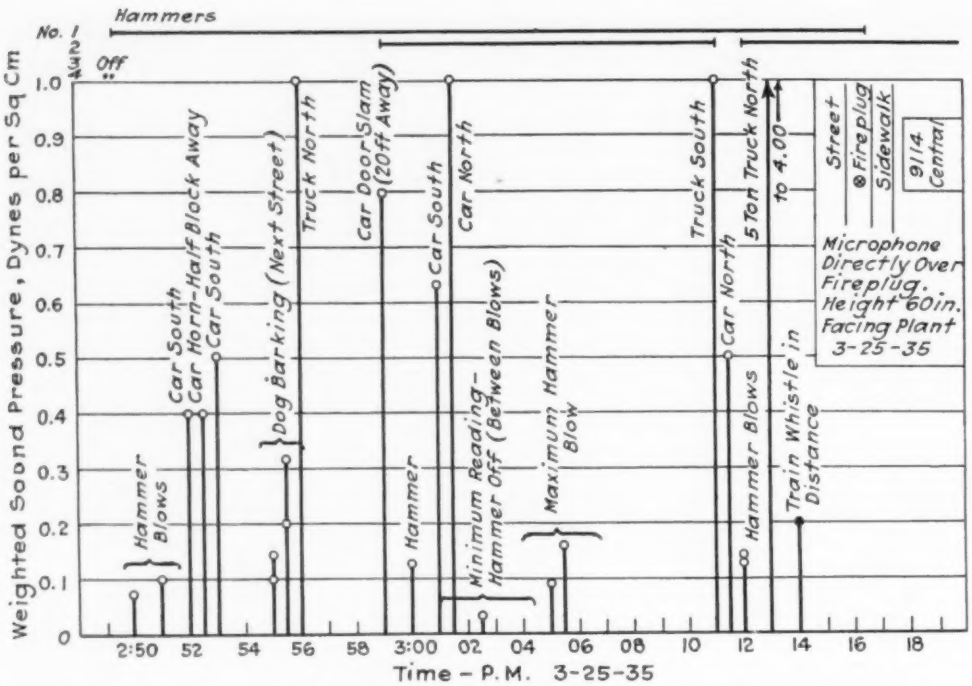

FIG. 12 DATA USED AS EVIDENCE IN COURT ON RELATIVE LEVELS OF VARIOUS NOISES

It is planned to reduce levels to the point where the noise cannot be heard on neighboring residential property.

Fundamentals:

1 The sounds involved in this case were primarily nonrecurrent as contrasted with the more or less continuous sounds frequently encountered in machinery. The hammers produced distinct and separate thuds, and most of the other sounds were of comparatively short duration.

2 The sound level varied over wide limits in the course of a few minutes, and the interest was primarily centered in the relative prominence of the various sounds at different times.

3 Present work in plant quieting indicates that noise should be taken into account in future construction of plants of this type. Since quieting involves hammer foundations, ventilation, illumination, and general design of the plant, it should be considered from the start.

4 The measurements were admitted as legal evidence, and the decision was consistent with the data.

NOISE SPECIFICATION FOR QUIETER DESIGN

Recently, the City of New York invited bids on a number of garbage dump trucks of the general design shown in Fig. 14. Among the specifications was included a limit on the noise of the hoisting mechanism. This limit was of the order of 10 decibels quieter than those in present use.

Fig. 13 shows a comparison of the noise of the present design and of a new design developed to meet the specifications. The measurements represent the average of readings at ten stations along the sides of the truck at a distance of one yard on the side of the body. It was found that the pump used on the original hydraulic lift produced prominent notes. Also the engine itself produced a higher level than was desired in the final installation. Since changes in the engine were not feasible, it was necessary to provide a pump of such a capacity that the lift could be made in the desired time with a much slower engine speed. In this way, the engine noise was reduced to the necessary value. The hoisting mechanism proper was quieted by means of an improved pump design and means for keeping the vibrations from being telegraphed to members which radiated them. The improvement in both the level and quality of sound was striking.

Fundamentals:

1 Noise specifications based on instrumental measurements are now in actual use.

2 Initial measurements showed the necessity of a pump design which would allow slower engine speed to achieve desired results

3 Improvements in design, isolation, and capacity, produced marked lowering of sound level and improvement in sound quality.

DETERMINATION OF NEW PRODUCT POSSIBILITIES

A company developed a new product which appeared might have possibilities in quieting automobiles. An investigation was undertaken to survey these possibilities. The problem was not so much what could be done with a given car of a given model, but what were the general possibilities. It might well be that a treatment which was effective under certain conditions would be put out of the running if some other change of design were made.

Measurements soon showed that the sound level in an automobile is determined by different factors under different conditions. For example, a comparison of curves 1, 2, and 5 of Fig. 15 shows that in this particular car at full throttle, the level is determined by engine noise. This is true on both concrete and gravel roads. Curves 6, 4, 1, and 3 show that on gravel road, the sound level is determined by noise originating in the running gear (often called "road noise") for all conditions

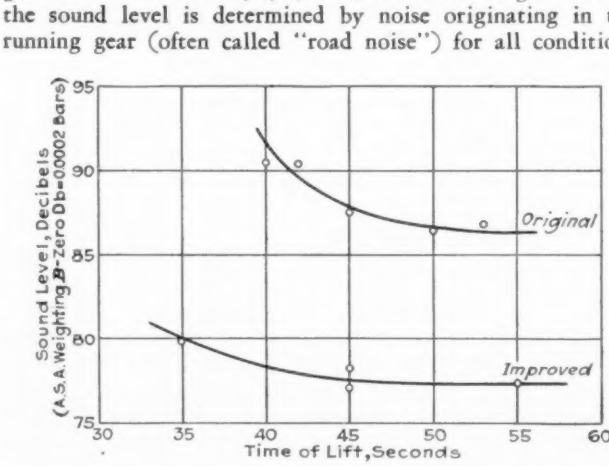

FIG. 13 NOISE LEVELS DURING HOIST OF TRUCK SHOWN IN FIG. 14

except full-throttle acceleration. Windage noise becomes important when other noises are sufficiently reduced. It seems quite likely that in the future "streamlining" for quietness will be more important than for style or fuel economy.

With the present style of car windows the noise is greatly increased when windows are opened. There are also large and rapid changes of level with open windows. These are indicated in Fig. 16.

Obviously, any particular quieting treatment is likely to be effective under some of these conditions, and not in others.

Further, it was necessary to measure the effect with variations in other factors. For example, engine noise predominates in the car tested under most conditions in spite of recent advances in engine mountings. Tests of material under the ultimate of engine quieting were easily obtained by making measurements with the car coasting at the desired speeds with the engine stopped. Tests under the condition of reduced road noise required considerable experimental change in the car.

During the course of this work, some rather startling quieting was obtained. The right-hand set of curves in Fig. 15 shows one experimental setup in which the sound level averages from 5 to 10 db below standard under all conditions. The sensation obtained in this car is far different from any other in which the author has ridden, and the lessening of the usual bombardment of the ears was most welcome. There seems to be no good reason why automobiles should not be much quieter than they now are.

Fundamentals:

1 Measurements showed that the sound level in automobiles is determined by different factors under different conditions. Hence a quieting move may be effective under some conditions and not others.

2 Noise admitted by open windows is an important factor in automobiles.

3 By making tests under various conditions, it was possible to determine the effectiveness of the material under study in present-day cars, and in much improved cars.

4 Experimental changes were made which gave conditions that were far quieter and more pleasing in sound than in present-day cars.

5 Much quieter cars appear to be entirely feasible.

SOUND LEVEL AND SOUND QUALITY BOTH IMPORTANT IN ACCEPTANCE TESTS

While the greatest value in acoustical measurements lies in determining how noises can be most effectively reduced, they are also useful at times in forming judgments as to the relative effectiveness of different devices. For example, in the automotive field there are continual decisions as to which of two or more products should be used on a job. Often it is difficult

FIG. 14 DUMP TRUCK FOR WHICH NOISE SPECIFICATIONS WERE PROVIDED

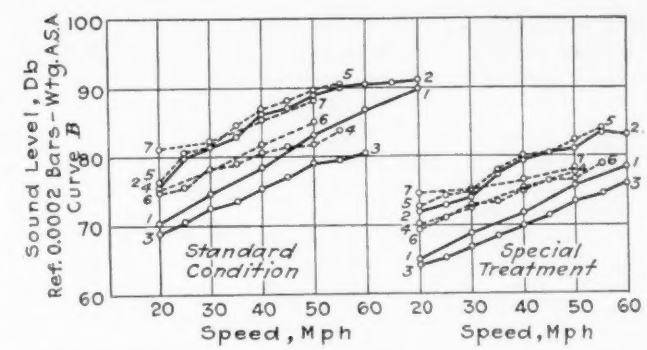

FIG. 15 NOISE LEVELS IN AUTOMOBILE UNDER VARIOUS CONDITIONS—WINDOWS CLOSED

(1 = steady speed, concrete road; 2 = full-throttle acceleration, concrete road; 3 = coast, concrete road; 4 = steady speed, gravel road; 5 = full-throttle acceleration, gravel road; 6 = coast, gravel road; 7 = "rumble" on rough spots of gravel road.)

indeed to remember the different comparisons by ear, particularly where considerable time elapses between runs.

Fig. 17 shows a comparison between two different types of automotive mufflers. Measurements were made of sound level near the end of the tail pipe at various speeds.

Two noises which have the same sound level may have extremely different characteristics due to different distribution of sound energy in the audible spectrum. In mufflers, in particular, there is a particularly disagreeable sound usually known to the industry as "spit." Often, the energy represented by the spit is not sufficient to affect the sound level greatly, but because of its distinctive character, it may be very disagreeable. Fig. 18 shows measurements taken to show the relative acoustical spectra of the mufflers shown in Fig. 17. These measurements were made with the aid of band-pass filters, each band being arranged to include one octave of the audible spectrum. The lowest octave covered from 50 to 100 cycles and the highest from 3200 to 6400. In the lowest two octaves, the two mufflers were about equally effective. In the 200- to 400-cycle octave the experimental muffler was not as effective as the standard. However, in the three highest octaves the experimental muffler was far superior to the standard. Tests have shown that these higher octaves are responsible for the spit and that comparatively low-pitched sound in the neighborhood of 200 cycles is quite well masked by other car noises. Accordingly, one obtains much better results from the experimental muffler than might be expected from the data in Fig. 17.

Practically all noise jobs involve components which are objectionable even though they do not contribute much to the total sound level. Means must be devised for measuring these components on the job. Sometimes this can be done by a frequency analysis, but in this particular case, the spit did not involve discrete frequencies, hence other means were required.

Fundamentals:

1 Acceptance tests based on actual measurements provide proper comparisons over periods of time and eliminate the personal equation.

2 Sound-level (total noise) measurements were not sufficient in this case.

3 Important differences in quality were present in impulsive sounds of unpitched character. Ordinary frequency analysis was of slight value on this problem.

4 By the use of octave filters the characteristic unpitched sounds were measured, and the observed differences in sound quality specified.

SPECIAL ACOUSTICAL TOOLS

Frequency analysis provided the means of diagnosis of many of the foregoing problems. In cases where the sound is essen-

tially unpitched in character, and intermittent in occurrence, frequency analysis is of little value. An excellent example of such a machine follows. In addition, this problem involved an obscure source which was located by very special adaptations of sound-measuring technique. Not only was the noise particularly unique in character, but the problem had received a great deal of attention previous to the use of acoustical measurements.

Since the early days of the domestic refrigerator, noise has been a problem. A great deal of work has been done to quiet the units and the results have been great. One company finally reached the point where all efforts to quiet the compressor further were ineffective. Experiment after experiment was tried, but the results were inconclusive. Sometimes, quieter units were obtained, but when the indicated changes were tried in production, there was no improvement.

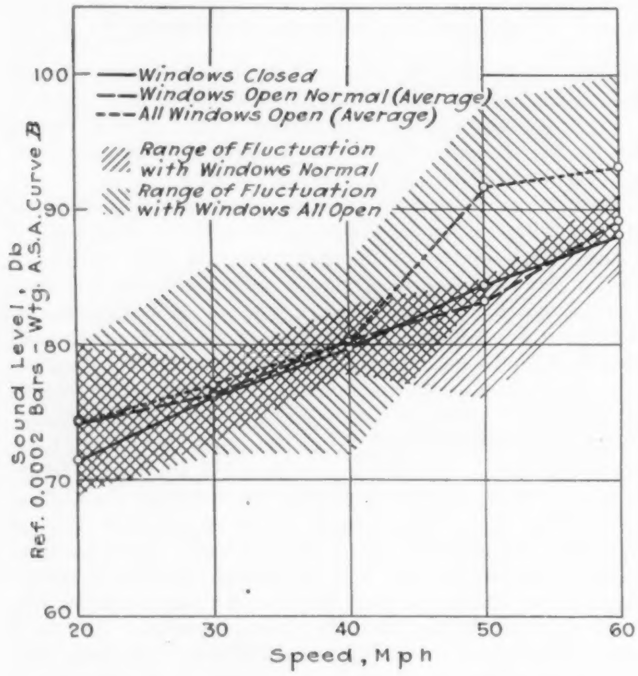

FIG. 16 NOISE LEVELS IN AUTOMOBILE—WINDOWS OPEN

("Normal" window openings as follows: Left front wide open, right front half open, and rear windows open about one inch.)

This problem had been worked so thoroughly that more powerful means of diagnosing the difficulties were indicated. Sound-level (total noise) measurements were of little use; they merely confirmed ear observations that some units were noisier than others. In the problems previously outlined, frequency analysis of the sound proved very useful. By this means, the various sources of sound could be separated and the parts of the machine responsible for each could be determined. Unfortunately, this technique was useless in the present case. Measurements showed that there were no musical components distinguishable from the rest of the noise. Somewhat larger readings were obtained when the analyzer was set in the neighborhood of 2000 to 2500 cycles but there were no notes in this or any other region. Other means of attack were indicated.

This compressor operated at about 10 rps and there was a rather distinct "tick" each revolution. It was decided to measure how much noise there was at each part of the stroke. This was accomplished by the setup shown in Fig. 19 which has been called an "acoustic stroboscope." The heart of this instrument is a cathode-ray oscillograph. The horizontal motion of the spot on the oscillograph was arranged so that it moved across the screen once each revolution of the compressor. This motion was synchronized by suitable contacts on the compressor itself. The noise was picked up by a suitable microphone, amplified, and applied to the vertical plates of the oscillograph. This combination gave a continuous picture on the oscillograph. As abscissas were shown the degrees of the revolution of the compressor, and as ordinates the sound level, thus giving a continuous indication of the noise at all parts of the stroke.

It was found that there was comparative silence during most of the stroke but there were certain intervals at which noise occurred. Some of these were short, lasting only a few thousands of a second, and others were much longer. At first, the sounds under test did not stand out very well, but by a suitable frequency weighting of the sound meter, the important sounds were well defined.

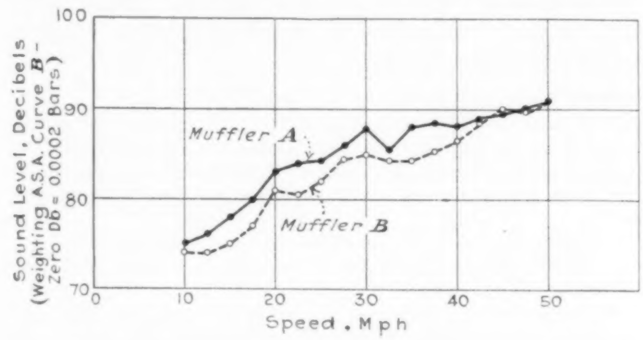

FIG. 17 SOUND-LEVEL (TOTAL NOISE) DATA OF AUTOMOBILE EXHAUST NOISE WITH TWO DIFFERENT MUFFLERS

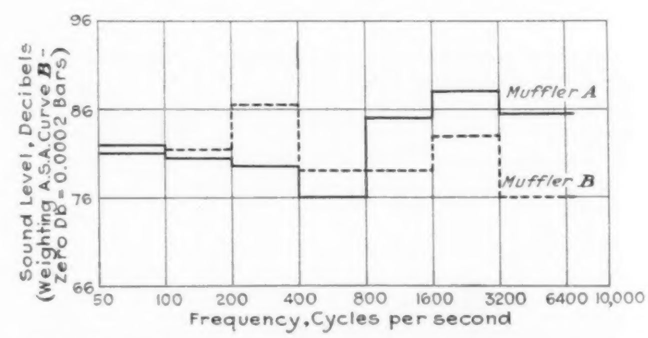

FIG. 18 ACOUSTICAL SPECTRA OF EXHAUST NOISE IN TERMS OF OCTAVE BANDS TO DETERMINE DISTRIBUTION OF SOUND ENERGY

(Objectionable "spit" was found to be unpitched sound in three highest octaves. Lower levels in these bands greatly improved the quality of the sound, although (see Fig. 17) the reduction in total sound level was not very great.)

By various experimental changes in the unit it was possible to reduce several of these noises, but there was one in particular which did not respond to treatment. The next step was to determine which parts produced this noise and how they were vibrated. This was accomplished by means of electrical contacts on various internal parts of the compressor mechanism. With the unit operating under any selected condition of temperature, speed, or load, the appropriate connections were made to the vertical plates of the oscillograph and the actions of the parts determined. In this way the source of the noise was soon located in a part which had never been suspected, and on which no work had been done. Once the difficulty

was properly diagnosed, a cure was designed which reduced this noise from 8 to 15 decibels on each machine tried, and hence eliminated this noise from consideration. This change involved one small machining operation and had no effect whatever on the efficiency, life, or general operation of the unit. The cost was considerably less than one cent per unit, and this modification is now in production.

Fundamentals:

1 Sound-level measurements were of little value in this case.

2 Frequency analysis was of little value.

3 Octave-band analysis was of little value.

4 Several different sources of noise were present, but it was difficult to determine what they were, or to separate their effects.

5 The noise was intermittent in character, but the pulses were so close together that ear separation was impossible.

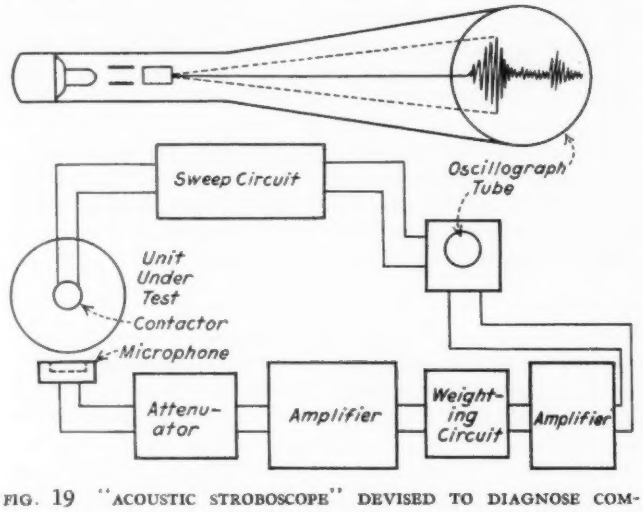

FIG. 19 "ACOUSTIC STROBOSCOPE" DEVISED TO DIAGNOSE COMPRESSOR NOISE WHICH COULD NOT BE HANDLED BY MORE COMMONLY USED MEASUREMENTS

6 It was necessary to devise and develop special acoustic tools to obtain the required information.

7 By means of special acoustical setup called an acoustic stroboscope it was possible to separate the noises which occurred at the different parts of the stroke.

8 Even this separation did not lead to a solution, because more than one part of the mechanism moved at periods of noise and experiments were ineffective.

9 The problem was definitely diagnosed by means of special contacts which measured the movements of various parts of the mechanism in operation, and allowed them to be correlated with the noise.

10 Once the problem was correctly diagnosed, a cure was devised which was both simple and effective.

CONCLUSION

These examples of actual machinery-noise problems illustrate to some extent the variety of factors encountered in this field. It has become axiomatic with us that each new job involves different points of importance and requires different techniques of measurement.

The characteristics of any sound can be measured in about as much detail as one desires. Theoretically, perhaps, one might proceed in a routine manner to measure all the characteristics of each sound in which he is interested. Practically, such an attack would be far beyond the realms of economic possibility in both time and cost. The chances are that the machinery would be worn out before the measurements could be completed. The only feasible method is to modify the attack and the technique of measurement to solve the problem at hand with a minimum of experimentation.

Most practical problems involve so many important factors that at best the number of measurements required is large. However, the complications exist whether one uses meters or not, and the meters do provide means of unscrambling the most complicated problems. Hence large savings often result from the use of instrumental methods through the elimination of costly experimental construction. The problems outlined in this paper indicate some of the flexibility and adaptability of instrumental attack.

Sound-level (total noise) measurements were sufficient in some of the problems. In others such measurements formed an important part of the data but were not sufficient. In others they were of no use at all. Frequency analysis is an extremely powerful tool by which many problems can be solved. These measurements are particularly valuable if one is interested in components of a sound which consists of musical notes which are reasonably constant in frequency. Such notes are frequently encountered, but most machinery noises include more or less unpitched sound. In many cases the unpitched sound forms the most prominent or objectionable parts of the noise. Frequency analysis is not particularly useful for dealing with this type of sound. Some sort of band analysis or special frequency weighting is required. Often the sounds are not constant with time, and some means must be devised to measure the time changes. The refrigerator compressor is only one example of this type of noise. All of these conditions were encountered in the problems described, and the list is by no means complete. Each new job seems to bring new and special conditions.

Acoustical measurements are most valuable when they are correlated with other knowledge of the machine; changes in its parts, measurements of the internal action, or peculiarities in the method of manufacture. As indicated, such correlations almost invariably yield unexpected information which leads to solutions of problems which might never be imagined otherwise.

Certainly, there is no reason why we should all live in such a sea of noise. The harmful effects and loss of efficiency are easily demonstrated. The relief which one experiences when noise is decreased by 5 to 10 db is almost beyond belief. A large proportion of this noise arises from some sort of machinery and there is no good reason why these could not be quieted.

In many cases it costs no more to build quiet machinery than it does to build noisy machinery. In fact, as shown in this paper, a decrease in production cost often accompanies a job of quieting. Obviously, such desirable results are not obtained by tacking some sort of an acoustical treatment on an otherwise noisy machine; the quietness must be built into it. The possible methods of quieting a machine are often many, and it is a question of determining the best way to obtain a given reduction. Acoustical measurements provide an effective and direct means of doing this work and lead to solutions which are practically impossible by ordinary methods.

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PEACEFUL REVOLUTION

By RALPH E. FREEMAN

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

"A PEACEFUL revolution is going forward in America today. It is proceeding quietly, without the fanfare of trumpets, without rancor, and without confusion. Its progress has been swift and sure. The figures given in this book[1] are the figures of today. Astonishing as they are, they will be invalid tomorrow; they will be replaced by statistics even more astonishing."

The revolution described is the cooperative movement which began in Rochdale, England, in 1844. It first appeared in the retail grocery field and contained the essential features of the cooperative societies which have since been formed in large numbers in other industries and in many other parts of the world. Its stockholders were grocery buyers, sales were made at competitive prices, and the profits, after a reasonable dividend on the stock, were prorated back to the members or stockholders in proportion to the value of their purchases from the store. The central idea was to give the "patrons" all profits remaining after the deduction of necessary expenses of handling the business.

The principle was soon applied to selling, and its greatest triumphs in this country have been achieved in the marketing of farm products. Since the cooperative marketing association turns back to its members the total sales price less selling expense, emphasis was at first laid on the advantage of eliminating the profit of the private middleman. But in recent years other advantages have been given increasing weight. When many farmers are induced to join the organization, its business becomes great enough to enable it to obtain the low costs of large-scale handling. The return to the farmer may be further increased by borrowing money and holding the crop off the market when prices are temporarily depressed. Moreover, the cooperatives have in some cases undertaken to grade the product, to educate their members in improving its quality, and to promote sales through the advertising of cooperative brands.

CLAIMS MADE FOR COOPERATIVES

"Consumer Cooperation in America," as the name implies, deals largely with the consumer type of cooperation and describes the developments that have taken place in this country during the last few years. Associations now active in the distribution and sale of gasoline, oil, tires, batteries, feed, fertilizer, milk, and general merchandise are described in more or less detail. Their struggle for existence against the competition of corporate business enterprises is depicted in vivid language and a glowing account is given of what they have accomplished for the consumer.

"In Rochester, Minnesota, is a cooperative organized in 1930. Its business the first year amounted to $60,000. In 1934 this cooperative did a business of nearly $350,000 and paid back to its consumer members $25,000 in patronage dividends. . . . The Grange League Federation was formed in 1920 and took over the job of purchasing. In 1934 G.L.F. did a business of $24,000,000. The average G.L.F. patron buys all his seed, feed, fertilizer, spray material, binder twine, and paint through his local G.L.F. store. At the end of the year he receives a report of the costs of service. He is shown what is spent, and for what it is spent. It is his business. With the report he receives as rebate the unexpended portion of the dollar he spent over the counter. . . . In Amarillo, Texas, the Consumers' Cooperatives, Associated, has built up a membership of 12,000 in the Texas Panhandle, New Mexico, and Oklahoma. It also deals in the farm supplies needed by its members, petroleum products, and automobile accessories. In 1934 this organization did a business of $4,000,000."

The chief aim of this movement, according to the author, is to obtain lower prices for buyers by eliminating "the parasitic middlemen" and by increasing the efficiency of distribution. Lower prices will result in increased sales, which in turn will permit enlarged production and employment.

SOME FACTORS TO BE CONSIDERED

Though the facts cited by the author of the book are arresting and significant as indicating an interesting trend in American economic life, the reader should bear in mind that the amount of business now being transacted by consumer cooperatives is small relative to the total sales of the country as a whole. Many of these societies owe their success to special conditions, such as the racial character of the cooperators or the exceptional weakness or inefficiency of competing organizations. It is a question whether the social cohesiveness, loyalty, and capacity for united action which are essential to the prosperity of cooperative societies are sufficiently common to insure the growth of the movement to large proportions. Cooperative societies are democratically controlled and it is extremely doubtful whether the qualities necessary for managing an efficient selling organization are possessed by the rank and file of consumers.

In a chapter entitled the "Revolt of the Guinea Pigs" the author explains how the cooperative movement will result in the debunking of advertising. "The cooperative movement is today concentrating on this business of advertising costs. It is educating its members in the waste and added consumer costs in advertising as a method of getting profits. And the masses of the people are easy to educate on this point. The present advertising methods, which border on the ridiculous, have already destroyed public confidence. The man who reads the cigarette advertisements as they are presented today is ready to see the falsity of reasoning behind the extravagant claims. The gasoline user who is affronted daily by the outrageous claims of the oil companies is more than receptive to the publicity that the cooperatives are giving the big oil companies." Whether the public is as susceptible to education as the author implies is perhaps open to question. Moreover, in many instances the very small unit cost of advertising is far outweighed by the economies of mass production which advertising makes possible. To develop markets sufficiently broad to permit large-scale production is one of the major difficulties confronting the cooperative movement.

(*Continued on page 728*)

One of a series of reviews of current economic literature affecting engineering prepared by members of the department of economics and social science, Massachusetts Institute of Technology, at the request of the Management Division of The American Society of Mechanical Engineers.

[1] "Consumer Cooperation in America. Democracy's Way Out," by Bertram B. Fowler, The Vanguard Press, New York, N. Y., 1936.

Maintenance and Use of

CEMENTED CARBIDE TOOLS

By LEO J. ST. CLAIR

CARBOLOY COMPANY, INC., PHILADELPHIA, PA.

PROPER maintenance and care have been generally acknowledged as being the most important factors in the successful use of cemented carbide tools. Manufacturers of cemented carbide are so firmly convinced on this point that much money and time have been spent on programs to educate users in better care and maintenance of tools made of this material, since they realize that their own success is intimately tied up with that of the users.

In the past year the development of a proper technique has made it possible to grind and sharpen cemented carbide tools far more quickly and with better results than ever before. Proper technique in the care of these tools has advanced so far that it is now no more difficult to take care of a carbide tool than it is to take care of other types of tools.

RECOMMENDED GRINDING PROCEDURE

Grinding technique has been developed along the lines of rapidity and safety. It is now recognized that the use of more than one clearance angle is an important factor in more rapid grinding without injury to the carbide tip. The supporting shank material is rough-ground with a clearance angle from 2 to 5 deg greater than the desired finish angle. On heavy-duty tools an angle 2 to 3 deg greater than the finished angle is considered proper. For light-duty tools the corresponding figure is 5 deg. Only the carbide tip is finish-ground to the desired final clearance. For example, assume that a finish-ground angle of 6 deg is required and that the tool is to be used for light duty. The rough grinding will be done at an angle 4 deg greater than the final clearance angle; therefore the shank and part of the carbide tip will be ground with a clearance of 10 deg. The tool is then finished with a clearance of 6 deg on the carbide tip only. Because of this the finishing wheel remains open and cuts freely and consequently produces a better cutting edge. Fig. 1 illustrates this procedure.

The use of double or composite clearance angles not only greatly reduces the time necessary to resharpen tools, but also introduces other factors that still further decrease the grinding time. In grinding with a cup wheel or a straight wheel it has been demonstrated conclusively that a slight crown prevents the wheel from loading rapidly since this crown greatly reduces the area of contact of the wheel and the tool and hence the amount of heat generated in the carbide tip. On straight wheels used for rough grinding the periphery is crowned about $^1/_{16}$ in. The face of the cup wheel used for roughing is also crowned about $^1/_{16}$ in. Fig. 2 illustrates the crowning of carbide wheels.

When carbide tools have been chipped, alternate grinding of the carbide tip and the steel shank is the most rapid method yet developed for removing large amounts of stock without injury to the carbide tip. Redressing is frequently required when grinding steel on silicon-carbide wheels. The steel loads the wheel rapidly; on the other hand the carbide tip dresses the silicon-carbide wheel. Therefore, by the alternate grinding of the carbide tip and the steel shank, the silicon-carbide wheel is kept open and cuts freely and rapidly, and continuous stock removal is obtained. This method of grinding

FIG. 1 USE OF COMPOSITE ANGLES IN GRINDING CARBIDE TOOLS

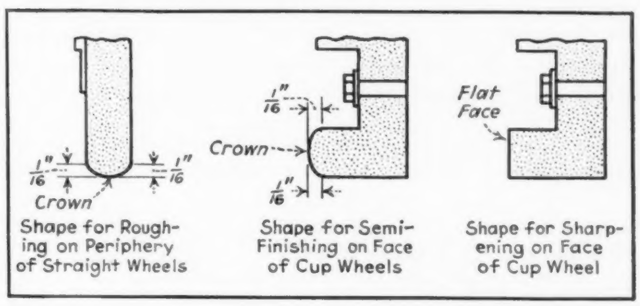

FIG. 2 PROPER DRESSING OF WHEELS

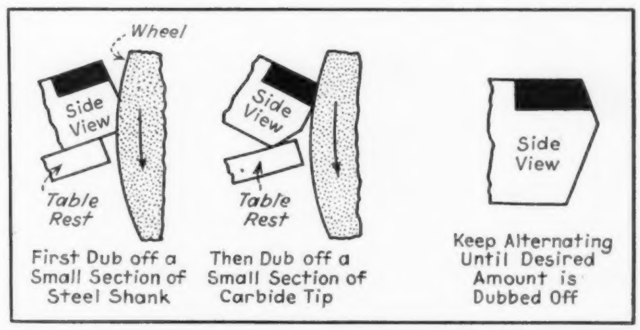

FIG. 3 ALTERNATE GRINDING ON CARBIDE TIP AND STEEL SHANK

is illustrated in Fig. 3. Alternate grinding is continued until sufficient stock is removed to start grinding the tool in the normal manner. Whenever possible, the steel shank should be ground on ordinary wheels intended for high-speed steel, and the remainder of the operation transferred to a silicon-carbide wheel intended for grinding carbide.

During most of these grinding operations it is important to keep the tool in constant motion. This prevents excessive

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heating of the carbide tip. First, the tool should be moved back and forth across the entire surface of the wheel. Next, while the tool is being moved across the wheel, it should also be rocked during the roughing and semifinishing operations. This rocking motion will aid rapid grinding. Fig. 4 illustrates the two motions.

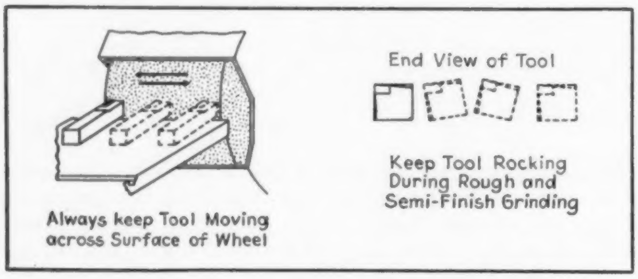


FIG. 4 MAINTAINING CONSTANT TOOL MOTION

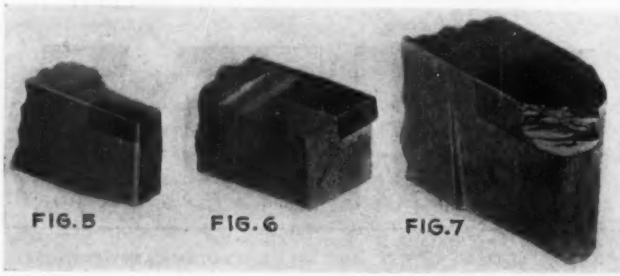


FIG. 5 ORDINARY DULL TOOL, $^{5}/_{8}$ BY $1^{1}/_{4}$ IN., COMPLETELY RESHARPENED IN 2 MIN 36 SEC

FIG. 6 MILLED AND BRAZED CARBIDE TOOL GROUND ON ALL SURFACES IN 4 MIN 36 SEC

FIG. 7 CARBIDE TOOL, $^{1}/_{2}$ BY $^{3}/_{4}$ IN., CHIPPED TO DEPTH OF $^{3}/_{16}$ IN., RECONDITIONED IN 3 MIN

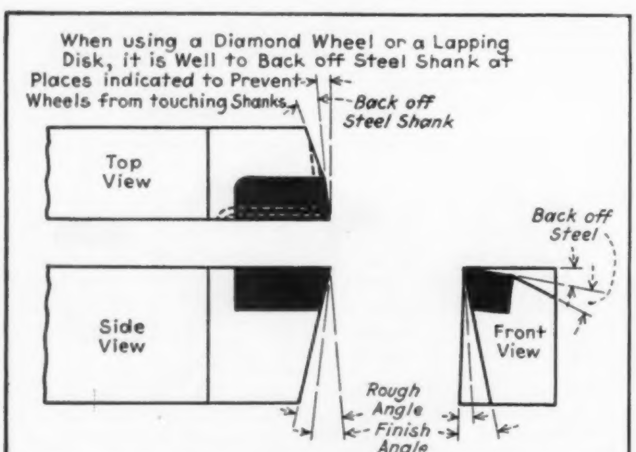


FIG. 8 WHEN USING A DIAMOND WHEEL OR A LAPPING DISK, GRIND STEEL SHANK AT PLACES INDICATED TO PREVENT WHEEL OR DISK FROM TOUCHING SHANK STEEL

It is now generally admitted that grinding on the periphery of a straight silicon-carbide wheel is more rapid than grinding on cup wheels, hence the straight wheel is recommended where a large amount of stock is to be removed. Care should be taken not to use a straight wheel having too small a diameter, since the small diameter tends to produce excessively concaved surfaces. After a straight wheel is used for roughing and semifinishing operations, the finished surface, which should be straight, is produced by means of a cup wheel. When a straight wheel is not available, somewhat similar results can be secured with a cup wheel by crowning as shown in Fig. 2.

By using the foregoing methods it is possible to grind very rapidly. A few examples will indicate the speed at which this grinding can be done. Fig. 5 shows a badly dulled $^{5}/_{8}$ by $1^{1}/_{4}$ in. tool which was completely resharpened in 2 min 36 sec. It was not uncommon practice to devote 20 to 30 min in resharpening such a tool before these methods were introduced.

Fig. 6 shows a milled and brazed carbide tool, all surfaces of which were ground in 4 min 36 sec.

Fig. 7 shows a $^{1}/_{2}$ by $^{3}/_{4}$-in. tool that was badly chipped to a depth of $^{3}/_{16}$ in. This tool was reconditioned in 3 min. In the past it was not unusual to take from $^{1}/_{2}$ to 1 hr to recondition such a tool. This rapid grinding is done without injury to the carbide tip.

PROCEDURE FOR FINISHING AND RESHARPENING

The procedure for finish-grinding or resharpening carbide tools is to use a fine-grain silicon-carbide wheel, a diamond wheel, or a lapping disk. The use of double or composite clearance angles has made all of these methods very rapid because little carbide material has to be removed to produce a sharp cutting edge. The most generally satisfactory and rapid method for finish-grinding or resharpening carbide tools is to use the diamond wheel. It is important with this method to use the double clearance angle and to grind away all of the steel surfaces that are in line with the carbide tip, so that the steel shank does not come in contact with the diamond wheel. This will insure a long life for the diamond wheel. The method of grinding is illustrated in Fig. 8.

It is important to lubricate a diamond wheel, and kerosene applied at the rate of 40 drops per minute is considered satisfactory lubrication. Such lubrication keeps the wheel clean so that it cuts freely. In using the lapping-disk method the same procedure should be followed. With a fine-grain silicon-carbide wheel it is not so important to keep the wheel away from the steel shank, but if the shank is relieved more rapid resharpening results. Silicon-carbide wheels for finishing should be of approximately 120 grain size. Such wheels will give a good finish and cut quite rapidly. By using 180- or 200-grit wheels, better finish can be secured at a sacrifice of resharpening time.

Because of the double clearance angle it is possible to resharpen carbide tools several times before it is necessary to regrind the secondary angles of clearance on the steel shank.

GRINDING AND SHARPENING MULTIPLE-POINT TOOLS

The principles already set forth for the care and maintenance of single-point tools apply also to other types, such as milling cutters, counterbores, and drills. Here also the double clearance angle is the greatest single factor in reducing resharpening time. Rough-grinding of these multiple-point tools should be done with the idea that the finish grinding is only a matter of producing a narrow land at the desired final angle. This will reduce wheel wear in case silicon-carbide wheels are used. This in turn decreases the need for checking sizes and naturally reduces sharpening time. If the diamond wheel or lapping disk is used, this method reduces wear and tear on these devices. The use of diamond wheels on multiple-point tools has been proved an excellent means of reducing the time needed to sharpen these tools, and makes their application successful because of the fine cutting edges and hence the accuracy that

can be procured. For this reason, the double clearance angle and diamond-wheel grinding are recommended wherever they can be used.

The care and maintenance of carbide tools on the part of the operator while using these tools is an important consideration. The operator can greatly lengthen the life of these tools by using a silicon-carbide or a diamond hone. Many operators have doubled the life of tools by the timely use of such hones. The diamond hone provides an easy method of touching up a tool without taking it out of its holder. Its use will greatly increase, once its value is appreciated by the operator. It is especially helpful in maintaining high finishes.

PRINCIPLES INVOLVED IN PROPER APPLICATION OF CEMENTED CARBIDE TOOLS

The proper application of cemented carbide tools has been given a great deal of consideration. The principles are well known but are important enough to bear repeating. They may be classified as follows: (1) Size of tool; (2) size of tip; and (3) tool support or overhang.

Generally speaking, a carbide tool is operated at least twice as fast as the high-speed-steel tool it replaces, and it is necessary to consider the added shock and pressure that it has to withstand. The impact shock varies as the square of the speed; therefore a tool cutting twice as fast, all other factors remaining unchanged, is subjected to much greater bending forces when unusual conditions are encountered. Since tungsten carbide has little elasticity, it is important that the tip be not subjected to severe bending forces, and the size of the shank must be great enough to withstand these forces. Carbide-tool shanks should be considerably larger than those of the tools they replace. Breakage is greatly reduced when large shanks are used.

Generally the depth of the carbide tip should never be more than one quarter of the depth of the shank. The tip should be thick enough and wide enough to absorb the shocks and pressures placed upon it by the cut. The length of the tip is important. When determining tip dimensions care must be taken not to use too great a length because of bending forces. A long tip is more likely to fracture than a short one. With short tips the braze will often absorb the bending forces to which the tool is subjected, which it cannot do if the tip is long; hence the long tip is more likely to break.

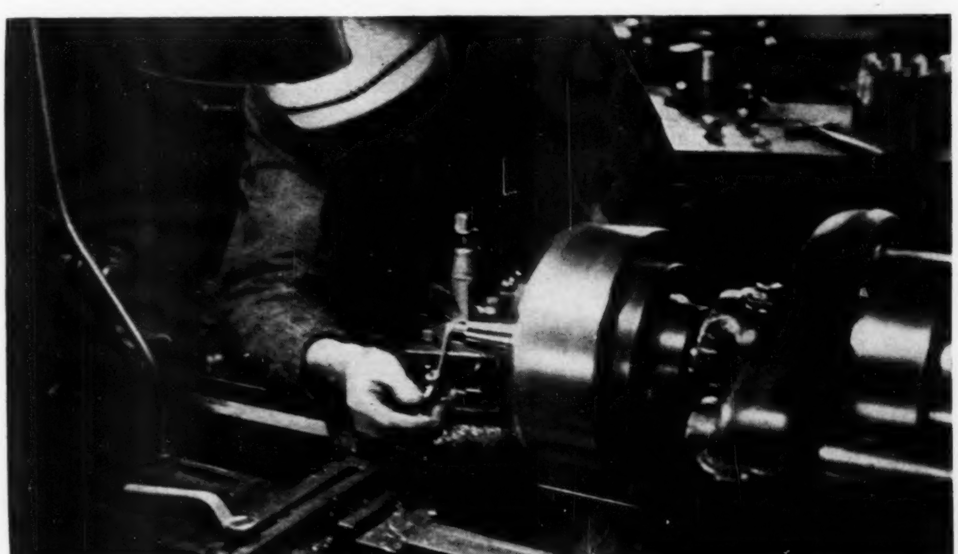
When considering tool support or overhang, it should be borne in mind that the amount of deflection at the end of the tool where the pressure of the cut is applied varies as the square of the distance from the point of support. Since this bending force must be kept as low as possible to prevent breakage or fracture, it is highly important to provide as short an overhang as possible. Excessive overhang has been responsible for much carbide-tool breakage.

It is now generally recognized that improper grinding methods have been responsible for much breakage. The manufacturers of grinding wheels recommend the use of a very soft silicon-carbide wheel rather than a hard one. A hard silicon-carbide wheel has a tendency to fracture the carbide material. Grinding fractures become visible only when the tool is etched with acid. By means of proper grinding technique, wheels, and grinding machines, this cause of breakage can be overcome.

SELECTION OF STEEL FOR TOOL SHANKS

The selection of shank steels by users who make their own tools is important in the prevention of breakage. Many tools have broken because the shank steel has had an excessive coefficient of expansion. Excessive expansion and contraction during heating and cooling processes set up great strains in the braze and in the carbide tip, which cause early failure. The author has seen many cases of tips badly cracked even before use, caused by using improper shank steel. If a user is in doubt about the proper shank steel to select, he should secure this information from the manufacturer. It has been found that a shank of a material similar to S.A.E. 2340 will have good brazing and expansion characteristics. Some users have successfully employed high-carbon tool steel and high-speed steel for shanks for light work; but with shanks of such materials low-temperature brazing mediums should be used, such as silver solder similar to Easy Flo no. 3. Because of the low temperature at which this brazing material melts, expansion and contraction of the tool shank during the brazing process are kept within limits that are not injurious to the carbide tips.

The maintenance and application of carbide tools depend largely on the amount of thought given to these subjects, and by using the principles brought out in this paper and other information obtainable from manufacturers, cemented carbide tools may be used successfully.



Jeannette Griffith

Peaceful Revolution

(*Continued from page 724*)

It should also be noted that in many cases the cooperatives have received preferential treatment by the government with respect to taxation, financing, and other aids. The United States Chamber of Commerce has recently issued a report criticizing such treatment, contending that cooperatives should be required to progress on the basis of their own merits. The American Retail Federation has also published a survey in which the same complaint is voiced. It is stated that while the federal law exempts from taxation only the dividends of farm cooperatives, six states exempt consumer cooperatives as well as the farm groups.

Though the book is informative, its chief purpose is to spread the gospel of cooperation. The existing business organization of the country is painted in black colors and much space is given to pillorying the "oil baron" and the other "overlords of the profit system." Cooperation is presented as a remedy for nearly all the economic ills which beset us: it will fill the pews of the churches and bring us international peace. "Consumer Cooperation builds for peace. In exchanging a system of production for profit for one of production for use, it takes the business of the nation out of the hands of the profit-makers, who are the war-makers because they profit by war, and puts it into the hands of the masses, who hate war because they are its victims. When there are no profits to be made out of war there will be no war. Just as logically there will continue to be war as long as someone can make a profit out of it—all the peace organizations and their plans to the contrary. The only way to eliminate war, therefore, is to eliminate profits. There is no other way."

But in spite of its many exaggerations, "Consumer Cooperation in America" is a significant and timely work: it calls to our attention a technique of industrial organization that is making considerable headway in this country.

Domestic Oil Burners

(*Continued from page 712*)

It should not be concluded from the foregoing that the comparative cost of heating is invariably inversely proportional to the efficiency of the boiler and burner. If all burners consumed the same grade of oil it would be substantially true that the fuel cost to do a given heating job would be approximately inversely proportional to the efficiencies of the boiler and burner combinations involved. It may be found that the differences in efficiencies of two types of burner under comparison may be more than offset by the difference in cost of the fuels supplied to the two types.

The difficulty involved in attempting to predict heating costs is shown by the following illustration. Investigations conducted by the Bureau of Agricultural Engineering showed that the seasonal cost of oil with a rotary wall-wiping blue-flame burner using No. 2 oil at $7^1/_2$ cents per gal was about 9 or 10 per cent greater than the cost of heating with a pressure-atomizing burner using No. 3 oil at $6^1/_2$ cents per gal, when these burners were used in a rectangular sectional boiler with liberal heat-absorbing surfaces. However, when used in a round boiler with rather limited heating surface the costs of oil were approximately equal, even though the No. 2 oil cost more per gallon than the No. 3 oil and in spite of the fact that the No. 3 oil contains a slightly larger number of heat units per gallon. It is important to note, however, that if the No. 2 oil had been supplied to both burners, which is commonly the case today, the cost of oil for the gun burner would have been higher than the cost of oil for the rotary burner in either type of boiler. In figures, the cost of oil for the gun burner in the round boiler would be about 18 per cent more than that for the rotary, and the cost of the oil for the gun burner in the rectangular sectional boiler would be about 5 or 6 per cent more than for the rotary. These figures obviously do not necessarily apply to all round boilers nor to all rectangular sectional boilers.

In conclusion it may be well to note that in selecting a burner for a particular installation there are other items, such as service and repairs, to be considered along with burner efficiency and fuel cost, and that when the different burner types are used with suitable boilers the differences in house-heating efficiency are not great.

The Port Washington Plant

(*Continued from page 704*)

pressure was used to increase gasket pressure rather than to lower it. Large bolted joints are maintained with difficulty at high pressures when bolt temperatures cannot always be maintained coincident with flange temperatures, but the internal "cover-type" joint is unusually reliable regardless of temperature variations.

The water level in the boiler is regulated manually with the aid of a steam-flow water-flow meter. The feedwater-control valves are motor-operated with fine regulation and are so designed that the flow of water through them will be practically proportional to the movement of the valve stem or the turning of the handwheel on the valve. The motors are controlled by push buttons located on the boiler operating panel. This method of control has proved to be a good insurance against trouble in emergencies. The simplicity of the entire feedwater system has been appreciated by the operators.

The performance of the high-pressure extraction heaters caused some concern at the start because preliminary tests showed them to be considerably under the guaranteed performance. The low heat-transfer rate obtained suggested coated tube surfaces, and an inspection showed rough surfaces, both inside and outside. The heaters had been released for manufacture early in the building of the plant, and evidently had been stored in improperly protected places for several years. To correct the difficulty, the tubes, which are of steel U-tube design, were sandblasted on the inside and pickled on the outside, with the result that the heat transfer is gradually improving and is now approximately 80 per cent of guarantee. The drain subcooling arrangement of the high-pressure extraction heaters used to reduce flash losses, has been operating satisfactorily.

It might be of interest to mention a leak which occurred on the gasket under the manhole cover of one of the heaters. A slight scratch-awl mark on the gasket was found to be the sole cause of the leak. This experience emphasizes the need for high standards of workmanship when dealing with high pressures.

CONCLUSION

Experience with this unit type of plant for advanced steam conditions indicates that it is reliable, easily operated, and economical. Its initial cost is slightly less than all previous installations on the system it serves, and its operating costs to date have been about two thirds of those of the Lakeside station. There is no doubt but that it represents an improvement in all respects.

HEAT TRANSFER *in* EVAPORATION *and* CONDENSATION[1]—II

By MAX JAKOB

THE FIRST three lectures of which this series of six is composed dealt with certain phenomena in evaporation. Lectures 4 to 6, which follow, relate to condensation. Lecture 4 takes up the subject of film condensation which has been improved somewhat by the author and his former colleagues. The fifth lecture contains the experimental proof of this theory, and the sixth, deviations from the theory and some recent ideas about dropwise condensation.

Fourth Lecture

I—INTRODUCTION TO THE LECTURES ON CONDENSATION

Since the properties of steam are exactly determined by the classical laws of thermodynamics, research work on these properties, although it can be treated from different points of view, is not ambiguous in its aims. This is not the case with research on the processes of production, use, and transformation of steam. Fundamental difficulties originate from the capillary energies between liquid, steam, and the walls, and from the manner of flow; consequently, also, from the quality and shape of the walls; and finally from the distribution of temperature and the exchange of heat. Therefore, in this field even the definitions and aims in general are uncertain, and still more so are the results, which depend on so many unknown variables.

The second series of these lectures deals with such a problem, i.e., the process of condensation. My own work on this subject arose in response to a question which confronted us in 1925: Whether saturated or superheated steam is more efficient as a heating fluid for evaporators and heat exchangers. At that time I was not yet aware that, in this general form, the question, as frequently occurs with questions asked in a friendly way in industrial quarters, has no scientific meaning. For in the question is contained an assumed knowledge of the kind of condensation; and at that time only the form known as film condensation was considered. Hence it was possible to give the theoretical solution immediately, and also the experimental one too in the course of a few years, but meanwhile the problem had been revealed as much more complicated, by recognizing that the drop form of condensation must also be taken into consideration, for although this kind of condensation had been known for a long time, it was considered too insignificant for technical consideration.

Thus, in the following lectures, it will be necessary (1) to describe two forms of condensation—film condensation and dropwise condensation and to explain the conditions relating to both of these forms and (2) to establish the theoretical and experimental foundations of knowledge, calculation, and control of condensation.

In what follows, for simplification I shall speak principally of water and steam; but what I shall say will also apply to other liquids and vapors. Furthermore, I shall deal mostly with vertical walls, particularly vertical tubes; although the theoretical and practical work known up to the present has also been extended to horizontal and oblique surfaces. In general, in these lectures, I am compelled to restrict myself to a selection of some of the most characteristic features of the condensation problem.

II—GENERAL DESCRIPTION OF TWO KINDS OF CONDENSATION

Film condensation occurs on a wettable cooling surface. A coherent film, covering the wall, flows down, driven by active mechanical forces, but is constantly renewed by the condensing steam, since the cooling surface is never free of water.

The process of wetting is essential only at the beginning of the condensation process. Once the surface is wet, only the binary liquid–steam system, need be considered, as the radius of curvature of the usual surfaces is so great that the effect of capillary forces disappears.

On nonwettable cooling surfaces the steam is condensed in drop form. The drops are extremely small when they originate, in accordance with the laws of capillarity. As they grow by further condensation, they roll down, under the influence of gravity and steam friction, and unite with other droplets, forming larger drops.

The conditions under which either kind of condensation occurs were first developed by the experiments of Schmidt, Schurig, and Sellschopp[2] in Danzig (1930), then by Spoelstra[3] in Java, by Roecke,[4] as well as by Jakob and Erk[4] in Germany and, particularly (1933 and 1935), by Drew and Nagle[5,6,7] and their colleagues at the Massachusetts Institute of Technology.

On the basis of these experiments Drew, Nagle, and Smith[7] have ascertained the following points:

> Clean steam, whether or not it contains noncondensable gas, always condenses in a film on clean surfaces, rough or polished.

[1] Last three of six lectures delivered to the Metropolitan and Philaphia Sections of The American Society of Mechanical Engineers; Armour Institute of Technology, Chicago, Ill.; Polytechnic Institute of Brooklyn, Brooklyn, N. Y.; University of California, Berkeley, Calif.; Columbia University, New York, N. Y.; Cooper Union, New York, N. Y.; The Franklin Institute, Philadelphia, Pa.; General Electric Company, Schenectady, N. Y.; Harvard University, Cambridge, Mass.; University of Illinois, Urbana, Ill.; Massachusetts Institute of Technology, Cambridge, Mass.; Newark College of Engineering; Pratt Institute, Brooklyn, N. Y.; Princeton University, Princeton, N. J.; Stevens Institute of Technology, Hoboken, N. J.; and Westinghouse Electric and Manufacturing Company, Philadelphia, Pa. The lectures on evaporation appeared in the October issue.

[2] E. Schmidt, W. Schurig, and W. Sellschopp, Technische Mechanik und Thermodynamik, vol. 1, 1930, p. 53.

[3] H. J. Spoelstra, *Arch. Suikerind. in Nederl.-Indie*, part 3, 1931, no. 23, p. 905.

[4] M. Jakob, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 76, 1932, p. 1161.

[5] W. M. Nagle and T. B. Drew, Trans. Am. Inst. Chem. Engr., vol. 30, 1933–1934, p. 217.

[6] W. M. Nagle, G. S. Bays, L. M. Blenderman, and T. B. Drew, Trans. Am. Inst. Chem. Engr., vol. 31, 1935, no. 4, p. 593.

[7] T. B. Drew, W. M. Nagle, and W. Q. Smith, Trans. Am. Inst. Chem. Engr., vol. 31, 1935, no. 4, p. 605.

FIG. 1 DROPWISE, FILM, AND MIXED CONDENSATION PRODUCED ON COPPER, NICKEL, AND ALLOY TUBE SURFACES, RESPECTIVELY, IN A VESSEL FILLED WITH CONTAMINATED STEAM

Dropwise condensation of steam does not occur unless the cooling surface is in some way contaminated.

Although numerous substances, while actually on the surface, will make it nonwettable, only those that are strongly adsorbed or otherwise firmly held are significant as drop promoters in a condenser. Some contaminants seem to depend for their activity as promoters on the amount of noncondensable gas present. Some contaminants are specifically effective on certain metals (e.g., mercaptans on copper alloys); others are quite generally effective (e.g., fatty acids).

It is understood that film condensation may occur on some parts of a cooling surface, and dropwise condensation on others. We shall call this "mixed condensation," as suggested by Roecke.

Drew and his colleagues obtained the three kinds of condensation in a single experiment, condensing steam on the exteriors of three tubes which they arranged in a glass vessel, Fig. 1.[8] The tube on the left was of copper, that in the middle of nickel, and that on the right of an alloy of nickel, copper, and zinc. Cooling these tubes by means of water flowing inside and using pure steam outside, all of them exhibited film condensation. With plant steam, on the contrary, the copper surface, adsorbing a contaminant (oleic acid?) contained in the steam, showed dropwise condensation with many fine-grained drops, the nonadsorbing nickel tube film condensation, and the alloy mixed condensation with a few coarse-grained drops.

Thorough studies of the two kinds of condensation are interesting from a physical standpoint and even more important for technical purposes. For, as we shall see, it has turned out that, on the same area, dropwise condensation is 15 to 19 times greater than film condensation. How can this be explained?

III—QUALITATIVE STATEMENTS ABOUT THE HEAT TRANSFER FROM A CONDENSING VAPOR TO THE COOLING SURFACE

Nusselt[9] developed a simple theory of film condensation in 1916. Qualitatively the main features of this theory are as follows:

Steam is condensing in a film on a vertical cooling surface. The film flows down, under the influence of gravity, but is retarded by the viscosity of the liquid. The heat of condensation passes through the film from the condensing steam to the wall. The film thereby resists the flow of heat, and, therefore, a temperature drop exists across it. The temperature of the surface of the film in contact with the wall is equal to that of the wall; and the surface of the film in contact with the steam is assumed to be at the saturation temperature.

If the latter plausible assumption is correct, the condensing steam is only in contact with a surface which is at saturation temperature, and therefore its condensability is limited. It is often remarked that the film opposes a strong resistance to the heat of condensation, which is to be conducted through it, and that the film becomes thicker as condensation proceeds, thus limiting its rate. This argument is not exact. For if the condensing steam is only in contact with a surface of liquid, and this is always at the saturation temperature, it is hard to comprehend how this vapor can know the thickness of the liquid layer on which the rate of condensation is said to depend. In other words, if the temperature of the film on the steam side is always exactly equal to saturation temperature, the same mass will be condensed, notwithstanding the thickness of the film. Therefore, the process must proceed in a somewhat different manner.

Reducing the temperature of a vertical cooling surface on which steam is condensing in a film increases the temperature drop across the film and therefore the flow of heat through it. At the same time the temperature of the water surface in contact with the steam is likewise decreasing, although by a very small amount only, but enough to increase condensation. This shows that theoretically the temperature of the liquid surface on the steam side of the film must be slightly below saturation temperature, and will be even lower with a colder cooling surface.

It seems to me that this modification of Nusselt's assumption is indispensable, since otherwise the increased condensation, caused by the lowering of the wall temperature, cannot be understood.

In any case, as remarked before, vapor, condensing in a film, is in contact with a fluid of nearly saturation temperature, and therefore the condensing effect is comparatively small.

On the contrary, when the dropwise condensation of steam takes place, the wall is in direct contact with the steam. Thus the effective temperature difference is much greater, and the formation of droplets takes place in a much more intensive manner than film condensation does. The growth of the drops, on the other hand, takes place according to the laws of film condensation applied to the surface of a droplet, but may be greater, in so far as the surface of a sphere is large as compared with that of a plane layer of corresponding thickness. Moreover, the coefficient of heat transfer is greater than that of a plane surface, the small curvature being an essential factor as

[8] I am indebted to Professor W. H. McAdams for placing this illustration, which is from his collection, at my disposal.

[9] W. Nusselt, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 60, 1916, pp. 541 and 569.

it is in the case of fine wires as compared with large cylinders. It must be added (at least for vertical and oblique surfaces) that the water is carried away more quickly, than in the case of film condensation, as the drops roll down and take other droplets with them. We shall return later to further peculiarities of the process, but first we consider quantitatively the process of film condensation.

IV—NUSSELT'S THEORY OF FILM CONDENSATION

For this purpose Nusselt combined the laws of laminar flow of a fluid film and of heat flow through it in the following manner:[10]

A fluid film, shown in Fig. 2, is flowing according to Newton's law

$$\tau = \eta \frac{dw}{dy} \qquad [1]$$

in which τ = the shearing strain in the fluid, and w = the velocity of flow, both at the vertical distance x from the zero point of condensation and at the horizontal distance y from the cooling surface, η = the coefficient of dynamic viscosity.

Then if γ denotes the specific weight of the layer, the equation of equilibrium is

$$d\tau = -\gamma\, dy \quad \text{or} \quad d\tau/dy = -\gamma \qquad [2]$$

Differentiating [1] with respect to y and substituting [2]

$$d^2w/dy^2 = -\gamma/\eta \qquad [3]$$

and by double integration

$$w = -\frac{\gamma}{2\eta} y^2 + C_1 y + C_2 \qquad [4]$$

Since the fluid adheres to the wall, the velocity at that point is $w = 0$, and Equation [4] becomes

$$C_2 = 0 \qquad [4a]$$

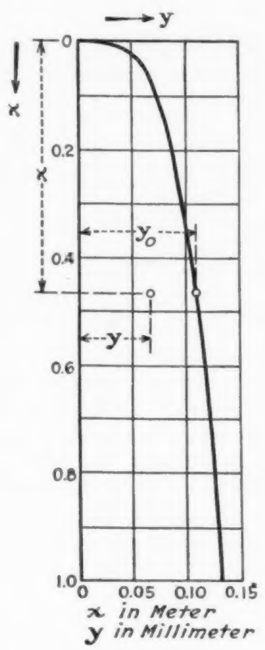


FIG. 2 GROWING OF A WATER FILM ACCORDING TO NUSSELT'S THEORY OF FILM CONDENSATION

Let $y = y_0$, the thickness of the film at the height x, and assume further that the vapor has no motion in the direction x and therefore that no friction exists between the vapor and the film. Then we find $(dw/dy)_{y = y_0} = 0$, and by differentiation of [4] and substitution

$$C_1 = \frac{\gamma}{\eta} y_0 \qquad [4b]$$

Substituting C_1 and C_2 in [4]

$$w = \frac{\gamma}{\eta} y_0 y - \frac{\gamma}{2\eta} y^2 \qquad [5]$$

and the mean velocity

$$w_m = \frac{1}{y_0} \int_0^{y_0} w\,dy = \frac{\gamma}{3\eta} y_0^2 \qquad [6]$$

According to Equation [6] the rate of fluid flow downward in unit time at the height x through the film section of the breadth 1, will be

$$G = \gamma y_0 w_m = \frac{\gamma^2}{3\eta} y_0^3 \qquad [7]$$

At the ordinate $x + dx$ the rate of flow is greater by

$$dG = \gamma d(y_0 w_m) = \frac{\gamma^2}{\eta} y_0^2 dy_0 \qquad [8]$$

This increase comes from the condensation on the differential height dx.

The quantity dG can also be expressed in terms of the heat dQ traversing the film in the area $1 \cdot dx$. Denoting the latent heat by r

$$dG = dQ/r \qquad [9]$$

Since we assume laminar film flow, the usual law of heat conduction can be applied, i.e.

$$dQ = \lambda \frac{\vartheta_s - \vartheta_R}{y_0} dx \qquad [10]$$

where

λ = the heat conductivity of the fluid
ϑ_s = the saturation temperature
ϑ_R = the temperature of the wall.

Substituting [10] in [9] we obtain

$$dG = \frac{\lambda}{r} \frac{\vartheta_s - \vartheta_R}{y_0} dx \qquad [11]$$

Thus, the condensing quantity dG is represented hydrodynamically by Equation [8] and in thermal quantities by [11]. Equating these expressions for dG we obtain

$$\frac{\lambda}{r} \frac{\vartheta_s - \vartheta_R}{y_0} dx = \frac{\gamma^2}{\eta} y_0^2 dy_0 \qquad [12]$$

and from this, by integration

$$x = \frac{r\gamma^2 y_0^4}{4\lambda\eta(\vartheta_s - \vartheta_R)} + C \qquad [13]$$

with $C = 0$, since $y_0 = 0$ at $x = 0$.
From [13]

$$y_0 = \sqrt[4]{\frac{4\lambda\eta(\vartheta_s - \vartheta_R)x}{r\gamma^2}} \qquad [14]$$

showing that the thickness of the film increases only with the fourth root of x.

Now substituting y_0 from [14] in [10] the heat flow becomes

$$q = \frac{dQ}{dx} = \sqrt[4]{\frac{r\gamma^2\lambda^3(\vartheta_s - \vartheta_R)^3}{4\eta x}} \qquad [15]$$

and integration of [15] over the entire surface of height h and the breadth 1 gives

$$Q = \frac{4}{3} \sqrt[4]{\frac{r\gamma^2 h^3\lambda^3(\vartheta_s - \vartheta_R)^3}{4\eta}} \qquad [16]$$

showing that Q is proportional to $[h(\vartheta_s - \vartheta_R)]^{0.75}$.

Introducing the coefficient of heat transfer, defined by

$$\alpha = \frac{q}{\vartheta_s - \vartheta_R} \qquad [17]$$

[10] In this derivation, first given by Nusselt, I follow, with but slight changes, that presented by H. Gröber and S. Erk, "Die Grundgesetze der Wärmeübertragung," Berlin, 1933, p. 205.

and substituting [15] we find

$$\alpha = \sqrt[4]{\frac{r\gamma^2\lambda^3}{4\eta x(\vartheta_s - \vartheta_R)}} \quad [18]$$

This coefficient applies to the position x; and a mean coefficient of heat transfer may also be obtained, defined by

$$\alpha_m = \frac{Q}{hl\,(\vartheta_s - \vartheta_R)} \quad [19]$$

which by substitution of [16] becomes

$$\alpha_m = \frac{4}{3}\sqrt[4]{\frac{r\gamma^2\lambda^3}{4\eta h(\vartheta_s - \vartheta_R)}} \quad [20]$$

α_m here being expressed (according to the original paper by Nusselt) in kcal per m per sec per deg C.

It may be mentioned here that α_m, as calculated for a vertical wall of height h according to Equation [20], may be multiplied by $0.77\sqrt[4]{h/d}$ in order to get the coefficient of heat transfer for a horizontal cylindrical surface whose diameter is d. We shall return to this in the fifth lecture.

These equations, established for condensation of saturated vapor, are also valuable for superheated vapor, the only change consisting in using $(i - i_c)$ instead of r, where i denotes the enthalpy (heat content) of the superheated steam and i_c that of the condensate carried away. Since $i - i_c > r$, it is evident from Equation [16] that film condensation of superheated steam will be more efficient than that of saturated steam.

The foregoing has presented the theory for steam not moving in the direction x. Nusselt has also extended the theory to steam flowing with constant velocity in the direction x. By introducing the shearing forces between steam and film surface and the increase of the film velocity w, caused by the flow of steam in the direction x, he obtains

$$w = \left(\frac{cw_D^2\gamma_D}{4\eta} + y_0\frac{\gamma}{\eta}\right)y - \frac{1}{2}y^2\frac{\gamma}{\eta} \quad [21]$$

where the subscript D refers to steam, and c is a constant derived from experiments on the friction of steam flow. We shall pursue Nusselt's way no further, but shall glance at the still more unpleasant one we had to follow in considering the case of decreasing steam velocity.[11] This occurs in steam flowing through a tube where it condenses. Nusselt's theory, in its original form, does not include this complicated case, and therefore we restricted our former experiments to a comparatively small rate of condensation, e.g., 10 per cent of the entering steam, the steam velocity in these limits being considered practically constant. But in our later experiments which were carried to much higher rates of condensation, the simple form of Nusselt's theory—although sufficiently complicated, even with w_D = const—was no longer adequate for an analytic reproduction of the results of our experiments.

I shall merely indicate our method.

If w_{D1} denotes the velocity of steam entering at the top of a vertical tube of diameter d_R, its rate of flow will be

$$G_{D1} = \frac{\pi}{4}d_R^2\gamma_{D1}w_{D1} \quad [22]$$

Analogously we have at the position x

$$G_D = \frac{\pi}{4}d_R^2\gamma_D w_D \quad [23]$$

On the other hand, since w_m is the average velocity of the film at the distance x from the upper end of the tube, the rate of flow of water at this point will be

$$G = \pi d_R y_0 w_m \gamma \quad [24]$$

As the rate of steam flow at position x will be smaller by this amount (compared to the entrance rate), we have

$$G_D = G_{D1} - G \quad [25]$$

and, from [23], the steam velocity at x will be

$$w_D = \frac{G_{D1} - G}{\frac{\pi}{4}d_R^2\gamma_D}$$

Substituting this in Equation [21] results in a new equation for w, and integrating this between the limits $y = 0$ and $y = y_0$, we find

$$w_m = \frac{B}{Ay_0^3}\left[1 + Ay_0^2 - \Phi(y_0)\right] \quad [26]$$

$$\left.\begin{aligned} \text{with } A &= cw_{D1}\gamma/d_R\eta \\ B &= d_R w_{D1}\gamma_D/4\gamma \\ \Phi(y_0) &= -\sqrt{1 + 2Ay_0^2 - \frac{2}{3}\frac{A}{B}y_0^4\frac{\gamma}{\eta}} \end{aligned}\right\} \quad [27]$$

As before we now express the differential of condensing steam dG in hydrodynamic and in thermal terms, and by setting these equal we come to our final differential equation

In deriving this equation we did not, as before, simply replace the latent heat r by the enthalpy of superheated steam i, calculating as though the heat transfer of superheated steam differed only from that of saturated steam by the difference of enthalpies, but used, more correctly, the following heat balance

$$r\,dG + \alpha_{Dm}\pi d_R\,(\vartheta_{Dm} - \vartheta_s)dx = \lambda\pi d_R\frac{\vartheta_s - \vartheta_R}{y_0}dx \quad [28]$$

α_{Dm} denoting the average coefficient of heat transfer between the superheated steam of an average temperature ϑ_{Dm} and the film.

Hence we find

$$\frac{1}{2B\gamma r}\left[\lambda(\vartheta_s - \vartheta_R) - \alpha_{Dm}y_0(\vartheta_{Dm} - \vartheta_s)\right]dx = \left[\frac{Dy_0^3 - 1}{\Phi(y_0)} + \frac{\Phi(y_0) - 1}{Ay_0^2}\right]dy_0 \quad [29]$$

In the case of saturated steam, the second term on the left disappears.

Equation [29] can only be solved by the calculus of differences. I should not like to repeat here the details of the manner in which we proceeded, which, briefly, was to divide the film into layers of uniform thickness, say, 0.01 mm or 0.03 mm.

In the following lecture the results of Nusselt's theory which we improved and extended in this way will be compared with the results of our experiments. The last lecture will deal with film condensation beyond the limits of Nusselt's theory, and with dropwise condensation, especially with certain consequences, that develop from the experiments, carried on at the Massachusetts Institute of Technology.

[11] M. Jakob, S. Erk, and H. Eck, *Physikalische Zeitschrift*, vol. 36, 1935, p. 73.

Fifth Lecture

V—EXPERIMENTAL VERIFICATION OF NUSSELT'S THEORY

1 ARRANGEMENT OF APPARATUS

The condensation of saturated and superheated steam flowing through a tube, cooled from the outside and held at a uniform temperature over its entire surface, may not be the most important case to be examined; anyhow it is the best defined. Therefore I settled upon this case and treated it, in cooperation with S. Erk and H. Eck, in several series of experiments that were varied and improved from time to time.

For these experiments we always used pure steam and smooth and clean surfaces, this being essential for film condensation, as pointed out at the beginning of the fourth lecture.

Our method is simple in principle. It consists in condensing part of the steam, entering at the top of a vertical brass tube, by means of cooling water that flows downward in a jacket surrounding the tube, and in condensing the remainder of the steam in a separate condenser attached to the lower end of the tube. By weighing all of the water formed by condensation, the total mass of entering steam is determined. By measuring the rate of flow and the temperature increase of the cooling water, the heat picked up by it is found; this is equal to the sum of the superheat energy, the latent heat, and the heat which the condensate loses as being cooled in flowing through the tube. In measuring further the temperatures of steam at the top and bottom of the tube, all data for a heat balance are available, and make it possible to calculate what amount of steam is condensed in the tube.

The steam coming from the boiler was first dried, electrically superheated, and mixed, in order not to show differences of temperature over the cross section in arriving at the upper end of the tube. The temperature of the cooling water could be raised by a preheater to any value up to 100 C. The flow of the steam and that of the cooling water were regulated automatically. The rate of flow of cooling water was made so great that the temperature rise remained small, so that the temperature of the wall was nearly constant over the length of the tube.

Fig. 3 shows the final form of the tube *a* with jacket *b* we used.[11] The cooled length of the tube was 1210 mm, the inner diameter 40 mm, and the thickness of the wall $3^1/_2$ mm, i.e., $^1/_8$ in. The transition pieces c_1 and c_2, determine the cooled length. Small tubes, laid into the wall of the main tube and soldered to it, contain thermocouples, that may be moved along the tube. In the jacket a resistance thermometer may be slid along the surface of the tube *a*. It consists of a small copper tube *l* in the form of a circle not completely closed, which surrounds the tube *a* at a small distance from the surface, and contains a platinum wire, passed to and fro four times through disks of steatite in which are four holes. The small funnel *m* narrows the jacket immediately ahead of the thermometer, thus guiding the cooling water to the resistance thermometer. The complete small arrangement *l*, *m*, *n*, *o*, *p*, *q* may be drawn upward by three fine bronze wires, and downward by two wires and a fine brass tube, which conducts the wires of the resistance thermometer out of the jacket. This tube and the five wires are brought through the top and the bottom of the jacket by means of small stuffing boxes.

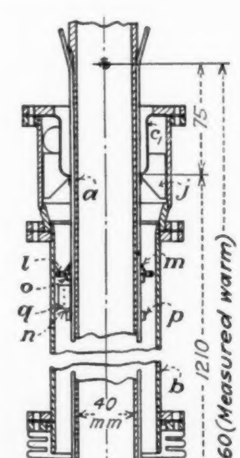


FIG. 3 APPARATUS USED IN EXPERIMENTS ON FILM CONDENSATION

This resistance thermometer enabled us to measure the increase of water temperature along the entire jacket and to determine in this way the heat acquired from the condensing steam all along the tube *a*. This method of measuring the temperature rise was employed only in a series of special experiments. In general the inlet and outlet temperatures of the cooling water were determined by thermocouples in chambers in which the water was well mixed. Such a chamber g, h, i_1, i_2, i_3, is shown in the upper right-hand corner of Fig. 4. This illustration[12] shows the ends of the tube *a* with jacket *b*, as well as sections of the thermocouples *k*, *l*, *n*, *o* in the walls and the method of drawing these thermocouples by means of wires and the pulley *m* through the fine tubes *k* and *l* and fixing their position by scales, in the lower right-hand corner. The most important arrangement, shown in this illustration, is a system of three fine tubes *p*, *q*, inside the tube *a*, one of which measures the static pressure, another the dynamic pressure, and the third, containing a thermocouple, the temperature. Each of these tubes can be brought to any point of the interior of the tube by the mechanism r, r_2, r_3, s, t, u, v, thus making it possible to determine the velocity and the temperature at every point. The arrangement does not interfere with the flow of the steam to be determined, since the measurement concerns only the flow of steam above the instrument. Fig. 5 illustrates the upper end of this instrument. The right one of the tubes *p* has an opening at the top (measurement of the sum of static and dynamic pressure); the next tube has a hole at mid-height (for the static pressure); the tube *q* contains the thermocouple. Passing on to the results of our experiments, which form the second part of this lecture, the reason for these arrangements will be recognized immediately.

2 SOME RESULTS OF EXPERIMENTS ON FILM CONDENSATION

See Page 845 for correction

I am compelled to restrict myself to only a few of our latest results. Figs. 6 and 7, embracing the results of 171 experiments, represent the density of the heat flow q_D in kcal per sq m per hr as a function of $\vartheta_s - \vartheta_{Rm}$, ϑ_s being obtain q_D in Btu per sq ft per hr and later on those of the coefficient of heat transfer α by 0.205, in order to obtain α in Btu per sq ft hr per deg F. The temperatures of our experiments refer to only two values, 212 F as the saturation temperature and 617 F as the entrance temperature of superheated steam.

(*a*) *Experiments on Vertical Tubes.* Fig. 6 refers to saturated steam at atmospheric pressure. The curves refer to steam entrance velocities of from 10 to 80 m per sec (33 to 260 ft per sec). The full lines represent the average of two series of experiments. The dotted lines represent the result, according to Nusselt's theory, extended and developed by us, as mentioned in the former lecture. It may be noticed that the curves issue from the origin of the diagram.

Fig. 7 refers to superheated steam, entering at 325 C (617 F). The curves for superheated steam diverge less than those for saturated steam and the agreement between experiment and

[12] M. Jakob, S. Erk, and H. Eck, *Forschung auf dem Gebiete des Ingenieurwesens*, vol. 3, 1932, p. 161.

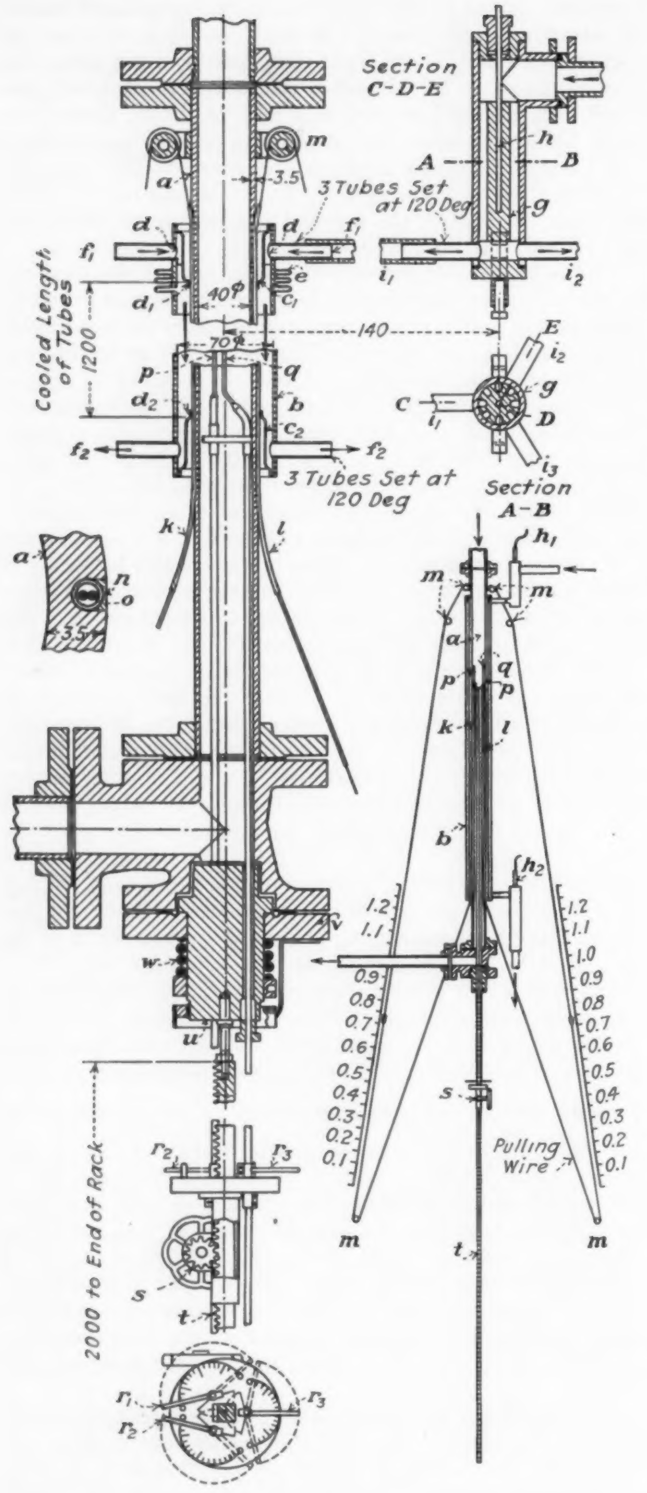


FIG. 4 FURTHER DETAILS OF THE APPARATUS USED

theory is somewhat better. While in Fig. 6 the curves issue from the origin of the coordinates, in Fig. 7 for wall temperature equal to saturation temperature, q_D has a finite value (cut off at the axis of ordinates), which is the heat transfer of the noncondensing steam at 325 C to a wall at 100 C.

In general a comparison of the two diagrams shows (1) that Nusselt's theory, applied correctly, leads to results qualitatively applicable over a wide range, these being almost better for superheated steam than for saturated steam, and (2) that the experimental curves are linear rather than parabolic.

In particular the comparison shows:

(1) That for large differences $\vartheta_s - \vartheta_{Rm}$ (i.e., in rapid cooling) the heat transfer observed was always better than calculated by Nusselt's theory. This is partially the result of dropwise condensation on the upper end of the cooling surface. At this point more water is formed than by film condensation. Farther down the drops of water run together so that on the lower part of the tube less heat is transmitted than is accounted for by the theory. Indeed, this was stated in connection with calorimetric measurements along the tube with the apparatus, mentioned in the fourth lecture. In Fig. 8, referring to the steam entrance velocity $w_{D1} = 40$ m per sec and $\vartheta_S - \vartheta_{Rm} \approx$ 27 C, as to be seen from a former paper,[12a] q_x denotes the density of heat flow at the position x, the observed values lying above the theoretical values in the initial third of the length and below in the remaining two thirds of the length. The full lines refer to saturated steam and the dotted ones to superheated steam, the difference being insignificant. The upper curve ϑ_W gives the temperature of the cooling water flowing outside the tube, this being used as the calorimetric fluid. Fig. 8 shows that

$$\left(\int q_x\, dx\right)_{obs} - \left(\int q_x\, dx\right)_{cal}$$

taken over the whole cooled length, gives a positive value and a larger one for superheated steam than for saturated steam, in accordance with the respective average values of Figs. 6 and 7.

At the highest steam velocities used by us, q_D may also be

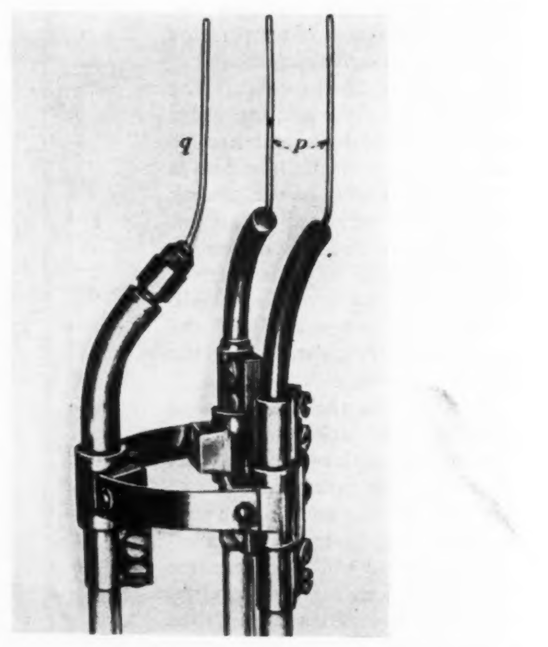


FIG. 5 UPPER END OF SHIFTABLE AND TURNABLE MEASURING INSTRUMENT

raised by the turbulence of the film. In Nusselt's theory laminar motion of the film is assumed. Recently, several researchers in the United States have pointed out that sometimes this condition may not be fulfilled in the case of rapid conden-

[12a] M. Jakob, *Centralblatt für die Zuckerindustrie*, vol. 42, 1934, p. 474.

sation. This problem will be treated in the sixth lecture. For the present, suffice it to say that our calculation shows that this may explain the difference between the results of our experiments and the Nusselt theory, at least in so far as the order of magnitude is concerned. Moreover, the greater increase of q_D at high values of $\vartheta_s - \vartheta_{Rm}$ and w_D (compared to the theoretical slope, see Figs. 6 and 7) may be partially caused by turbulence of the film.

(2) For small values of $\vartheta_s - \vartheta_{Rm}$ the experiment yields lower values of q_D than the theory, particularly at the high entrance velocity $w_{D1} = 80$ m per sec. It is obvious to think of undercooling of the steam; the calculation shows that in this case the tube would remain entirely dry over the first third of its length. With superheated steam we did not find this effect; but in the field of lesser cooling the accuracy of our experiments

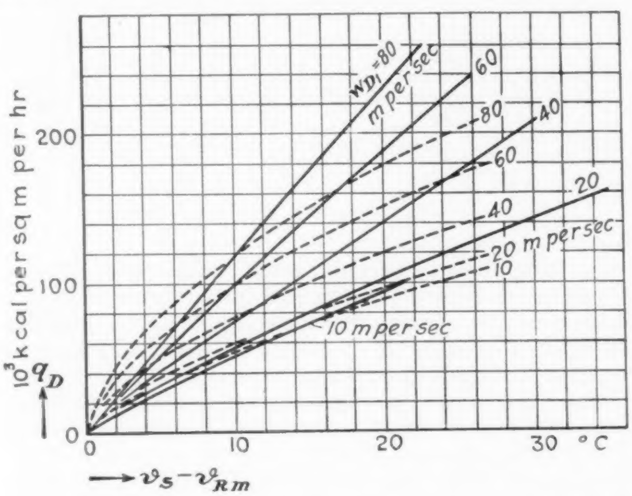


FIG. 6 HEAT TRANSFER BY CONDENSATION OF SATURATED STEAM, AT ATMOSPHERIC PRESSURE

(Full lines, average of experiments; dotted lines, extended Nusselt theory.)

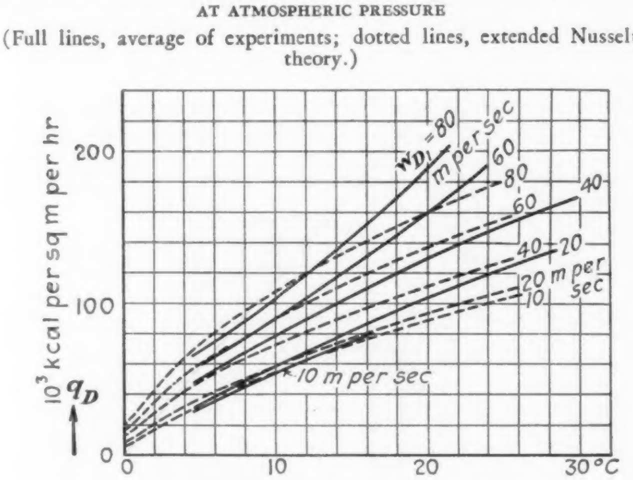


FIG. 7 HEAT TRANSFER BY CONDENSATION OF SUPERHEATED STEAM AT ATMOSPHERIC PRESSURE AND 325 C

(Full lines, average of experiments; dotted lines, extended Nusselt theory.)

seems to be insufficient to decide the question. We shall return to this point in the next lecture.

For practical purposes the results of our experiments may be represented by the empirical equation

$$q_D = (3400 + 100w_{D1})(\vartheta_s - \vartheta_{Rm})(1.21/l)^n \ldots\ldots [30]$$

for saturated steam, and, for superheated steam the equation is

$$q_D = (3500 + 51w_{D1})(\vartheta_s - \vartheta_{Rm})(+ 5.3)(1.21/l)^n \ldots [31]$$

The diameter of the tube might have an influence, because the steam velocity decreases faster in a narrow tube than in a wide one, so that in the latter the mean heat transfer would be

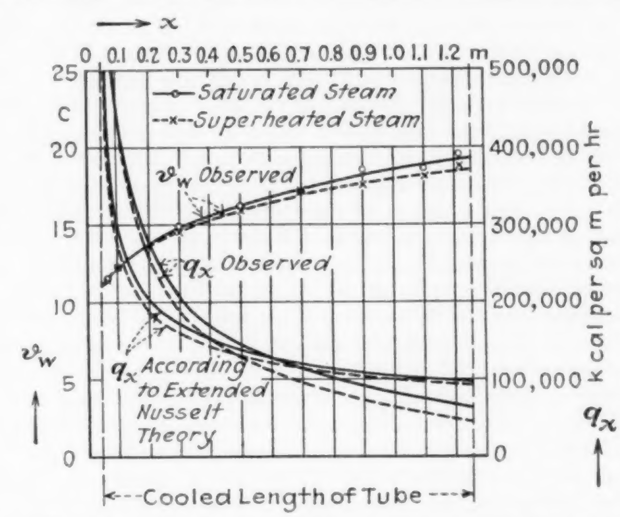


FIG. 8 TEMPERATURE OF COOLING WATER AND DENSITY OF HEAT FLOW ACROSS THE WALL AS MEASURED OVER THE COOLING LENGTH

better, assuming the entrance velocity of the steam is the same. However, calculation has shown that in a tube 1.2 m long and 80 mm in diameter, the condensation of steam that enters with the velocity of 40 m per sec, is but 3 per cent greater referred to same surface area than in a tube with an internal diameter of 20 mm. The influence of the length of the tube is expressed in the exponent n, which lies between 0.25 and 0.33, according to Nusselt's theory. In some measurements with $l < 1.21$ we found $n = 0.38$, instead of 0.33. For practical purposes it will generally suffice to take $n = 1/3$.

Summarizing the results of our principal experiments, I should like to repeat that they refer to clean and smooth surfaces on which film condensation prevailed. However, a small amount of dropwise condensation, as well as turbulence of the film at high steam velocities, also existed and have been considered in establishing Equations [30] and [31]. These secondary influences seem to effect the rather linear course of our curves. Extrapolation far beyond the limit of our experiments is of questionable value. For $w_{D1} < 10$ m per sec Nusselt's simple theory, as it relates to quiescent steam, seems to be in better agreement with reality than do our empirical equations.

The results of experiments, previously quoted, were obtained by calorimetry over the entire length of the tube or over certain parts of it. The following example shows that this is not always adequate.

In measuring the temperature along the axis of a cooled tube through which superheated steam was flowing, we observed the anomaly that, in cooling the wall more effectively the superheat of the steam decreased less than it did with less cooling.[13] We succeeded in explaining this phenomenon in the following manner: Cooling of the core of steam, apart from expansion, is caused by hot (i.e., fast moving) molecules coming out of the core, then touching the colder (i.e., slower moving) molecules (these belonging to zones near the surface),

[13] M. Jakob, S. Erk, and H. Eck, "Technische Mechanik und Thermodynamik," vol. 1, 1930, p. 46.

and finally returning cooled (i.e., with retarded velocity) into the core. If, on the other hand, the wall is so cold that all molecules leaving the core are held at the wall surface by condensation, the core cannot be cooled at all.

We put this hypothesis to test by measuring the distribution of temperature and velocity over cross sections and axial sections of the interior of the tube, as previously described. Thus we obtained the diagrams reproduced in Fig. 9 in which I and IV relate to the upper and lower ends of the tube, and II and III, to vertical distances of 25 and 75 cm from the upper end. On the left, with slow cooling, the original parabolic distribution of steam velocities w_D over the cross section flattened but little and the velocities became only insignificantly smaller, this indicating only a slight radial flow in the direction to the wall. In rapid cooling, on the other hand, the reverse was true, as may be seen in the second set of curves. The third diagram relates again to slow cooling. Here the distribution curves of steam temperature ϑ_D are flat at first and then become parabolic, and the temperature ϑ_D decreases considerably, as a result of the cooling effect of the wall, which tended to equalize the temperatures of the wall and of the flow core. However, there was only little change, if we cooled rapidly (see fourth diagram), the temperature difference between the axis and the wall remaining nearly the same. Thus our observations reproduce perfectly the exchange of impulse and temperature and give balances of the quantities of steam as well as of the amounts of heat energy for each point in the interior of the tube. By such a procedure many strange phenomena, connected with condensation, may be cleared up.

(*b*) *Experiments on Horizontal Tubes.* While in general our experiments were conducted on vertical tubes, we also examined the behavior of horizontal tubes in several series comprising 146 experiments in all.[14] The main difficulty lies in the inevitable differences of temperature in the wall of tube (this being 460 mm long and 17 mm in diameter). As in the case of the experiments on vertical tubes, we arranged movable thermocouples in two small tubes along the wall. By rotating the tube on its horizontal axis it was possible to investigate the distribution of temperature in the wall at any angle.

[14] M. Jakob, S. Erk, and H. Eck, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 73, 1929, p. 1517.

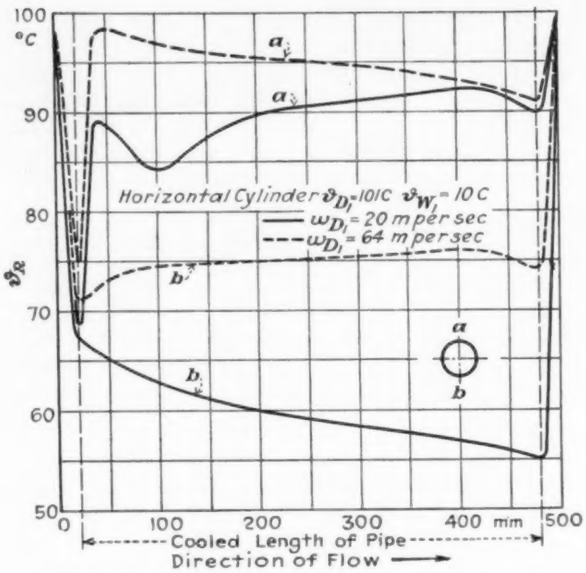


FIG. 10 WALL TEMPERATURE ALONG A HORIZONTAL TUBE IN WHICH SATURATED FLOWING STEAM IS CONDENSED

The better heat transfer for a horizontal cylindrical pipe that is not too short, as mentioned in the fourth lecture, is chiefly caused by the fact that the water tends to run off the top of the horizontal pipe, so that the water film becomes very thin, and the heat transmission very great, at that point. As shown in Fig. 10, the wall is much hotter at the top (at *a*) than at the bottom (at *b*). The illustration shows the variation of wall temperature ϑ_R along the pipe, the base being the cooled length of 460 mm, and the entrance temperature of the cooling water being ϑ_{w1} = 10 C. The full lines refer to the entrance velocity of steam w_{D1} = 20 m per sec, and the dotted lines to w_{D1} = 64 m per sec. The differences of temperature between *a* and *b*, in the first case, reach 35 C, the mean wall temperature being about 73 C.

Still more instructive is Fig. 11, which refers, to superheated steam at ϑ_{D1} = 325 C (617 F), entering with velocity w_{D1} =

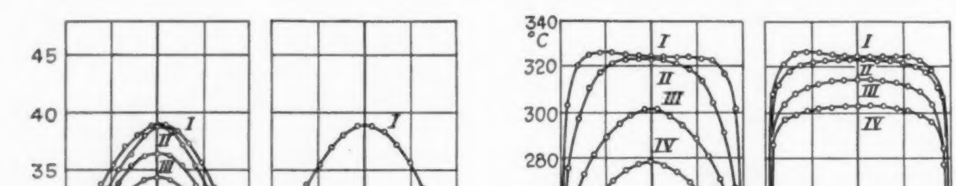


FIG. 9 DISTRIBUTION OF VELOCITY AND TEMPERATURE OF SUPERHEATED STEAM CONDENSING IN A VERTICAL TUBE

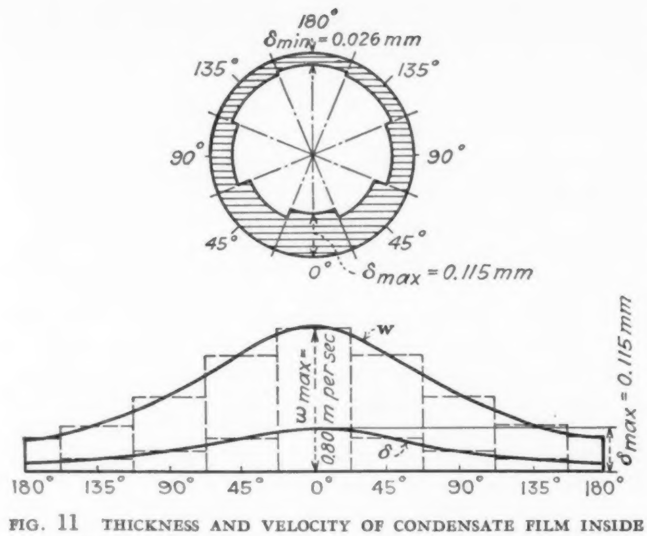


FIG. 11 THICKNESS AND VELOCITY OF CONDENSATE FILM INSIDE A HORIZONTAL TUBE IN WHICH SATURATED FLOWING STEAM IS CONDENSED

95 m per sec. In the upper part of this, the thickness of the water film is recorded, the scale being 30 times as great as the scale of the pipe diameter. The thickness of the film on the top is only 0.026 mm, but on the bottom it is 0.115 mm, which is almost five times as great. In the lower diagram, the lower curve shows the variation of the film thickness as a function of the location on the perimeter, expressed in terms of the angular positions indicated in the upper diagram. The upper curve represents the velocity of the water film, with a maximum of 0.80 m per sec at the bottom. The inner film at the top of the horizontal pipe is moved much more slowly by the flow of steam. The observed mass of the condensate was 6.28 kg per hr, whereas from the represented distribution of the water film and its velocities, it was calculated as 6.47 kg per hr, which is in good agreement with the observed mass.

Thus in this lecture we have verified to a considerable extent the assertions of Nusselt's theory. The final lecture will deal with those cases, in which the theory is not applicable, i.e., the cases of turbulent water film, undercooling of the steam, and, particularly, dropwise condensation.

Sixth Lecture

VI—POSSIBLE DEVIATIONS FROM NUSSELT'S THEORY OF FILM CONDENSATION

1 SMALLER TEMPERATURE DROP ACROSS THE WATER FILM

In the fifth lecture we dealt with the cases of condensation in which Nusselt's theory held. In the present lecture we shall treat the other cases. One of the consequences of Nusselt's theory with which we have become acquainted is, that heat transfer will be somewhat better for superheated steam than for saturated steam. But experience in practice has shown that evaporators are often working less efficiently with superheated steam than with saturated steam. The reason has not yet been definitively explained. In 1928 I remarked[15] that in the condensation of superheated steam the steam-side surface of the film might be at a temperature essentially below saturation temperature. In 1932 Bošnjaković[16] took up this hypothesis and attempted to prove it theoretically. With several assumptions about the number of steam molecules invading the film and those emitted by the surface, which he calls respectively, "invading" and "evading" molecules, he computes that in order to condense steam at atmospheric pressure and at a temperature of 325 C the temperature of the wall must lie at least 7 C below the saturation temperature of 100 C. He tries to explain this in the following manner: A certain molecular density is necessary for condensation. Since saturated steam has this density, it can be condensed at a wall that is only slightly undercooled. On the other hand, superheated steam of the same pressure has a lower density and cannot be condensed unless the temperature of the wall is considerably below the saturation temperature.

Examining these assertions it ought not to be forgotten that explanations of heat transfer based on molecular behavior and on the phenomenon itself are but different aspects of the same subject. Bošnjaković speaks of molecules of superheated steam, i.e., very fast molecules, plunging into the liquid. If this had a temperature not considerably lower than that of saturation, the cold energy necessary for cooling the superheated steam, i.e., for stopping the molecules, would not be available. Consequently, the water-film would be quickly heated at or slightly above saturation temperature and thus the condensation would be interrupted. On the other hand, considering the phenomenon itself, this means that the coefficient of heat transfer between superheated steam and the surface is so much less than between saturated steam and the surface that, at first, little or no superheated steam can be cooled to saturation temperature and then condensed, and hence

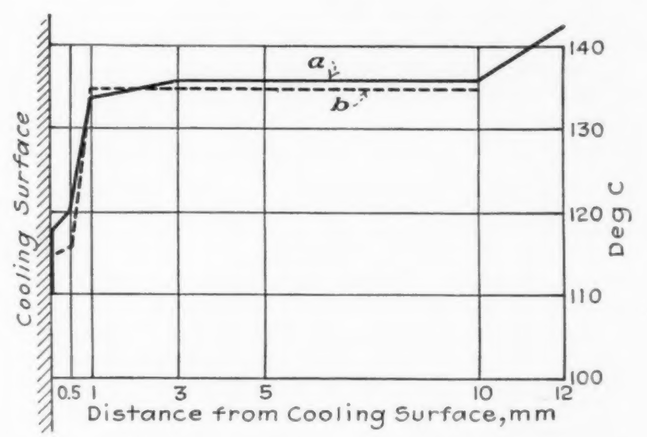


FIG. 12 ROECKE'S OBSERVATIONS ON TEMPERATURE DISTRIBUTION IN CONDENSING STEAM

the cooling effect of the wall preponderates and reduces the temperature of the water film.

Hence, both of these explanations might lead to the following paradoxical assertion: If the intensity of cooling remains unchanged while the temperature of the steam is raised as it issues from the saturated state, the temperature of the film will not increase but will decrease. A similar anomaly that we observed in our experiments has been dealt with in the fifth lecture.

In this lecture I should merely like to mention:

(1) That the possible rate of undercooling of the film probably has a lower limit in the thermodynamic Wilson line, because, in this state, as far as is known up to the present, any quantity of steam will be condensed, so that the temperature of the film would be unable to drop further.

[15] M. Jakob, *Forschungsarbeiten auf dem Gebiete des Ingenieurwesens*, no. 300, 1928, p. 14.

[16] F. Bocnjakovic, *Forschung auf dem Gebiete des Ingenieurwesens*, vol. 3, 1932, p. 135.

(2) Superheated steam flowing downward in a tube, the temperature of which is lower than saturation temperature, will probably remain uncondensed for a short time at first. Then it will pass into a superheated core with a saturated steam envelope which borders on the film surface. Thus, after a certain interval, according to Nusselt's assumption, the steam-side surface of the film will be at nearly saturation temperature.

Because of this it may be possible to explain the distribution of steam temperature, which Röcke[4] observed in an annular space, 24 mm in diameter, into which steam entered at the top, with the outer wall insulated and the inner wall at $\vartheta_R = 107.3$ C. Fig. 12 shows the distribution of temperature 55 cm below the top (*a*), and 105 cm below the top (*b*). It seems that adjacent to the wall there exists a region one mm thick where the temperature is falling from 135 C to saturation temperature, in this case 110 C. The uniformity of the temperature at points between 10 mm and 1 mm distant from this wall would indicate that particles of steam moving from this zone to the left will not return, but will be condensed. The region one mm thick near the wall seems to be a transition layer that contains a mixture of superheated and saturated steam.

It is worthwhile mentioning the fact that for the case of steam with a certain air content D. F. Othmer as well as E. F. M. van der Held[17] suggest the existence of a transition layer, rich in gas and presenting a resistance to the diffusion of steam through it, in this way explaining that any air content makes much more difficult the process of condensation. In this case, because the partial pressure of steam at the steam-side surface of the water film is much lower, the temperature will also be lower there.[18] Therefore the temperature drop across the film will also be smaller. I should like to point to the fact that otherwise, in consequence of the theory the film should be thicker, corresponding to the smaller amount of heat, crossing it. On the other hand a thicker water film flowing down more quickly, might indicate more rapid condensation. I do not see how this discrepancy of theory and experience should be overcome unless by the assumption of the forementioned transition layer.

2 TURBULENCE OF THE FLUID FLOWING AS A FILM

Nusselt's theory assumes laminar flow of the film. In more recent publications in the United States it is shown that this assumption does not always hold. At a meeting of the American Institute of Chemical Engineers in December, 1933, Cooper, Drew, and McAdams,[19] as well as Kirkbride[20] and Colburn,[21] pointed to the fact that the Reynolds number Re, essential for the transition of a liquid layer of the density ρ into turbulence, is not $w_m y_0 \eta/\rho$, but $w_m 4y_0\eta/\rho$, since $4y_0$ is the diameter of a cylindrical tube, hydrodynamically equivalent to a plane layer of the thickness y_0. Thus the limit of possible turbulence of the film is recognized as four times less than one might think without this consideration. The critical value of Re is said to be about 1500 or 1600. In our experiments, dealt with in the fifth lecture, we reached Re $\approx$ 2300, and turbulence in the water film thereby apparently raised the rate of condensation, as pointed out in the former lecture.

Based on experiments with water, carried on by Callendar and Nicolson and by Jordan (until Re = 4000) and on experiments with diphenyl, conducted by Badger, Monrad and Diamond (until Re = 30,000), Kirkbride has shown that the dimensionless equation

$$\alpha_m = \left(\frac{\eta^2}{g\rho^2\lambda^3}\right)^{1/3} = 1.468\ (\mathrm{Re})^{-1/3} \qquad [32]$$

derived by him from Nusselt's equation for laminar motion, can be replaced by

$$\alpha_m = \left(\frac{\eta^2}{g\rho^2\lambda^3}\right)^{1/3} = 0.0076\ (\mathrm{Re})^{2/5} \qquad [33]$$

According to Equation [32], the term $\alpha_m \left(\frac{\eta^2}{g\rho^2\lambda^3}\right)^{1/3}$ decreases from 1.47 to 0.147 when Re rises from 1 to 1000, and according to Equation [33] it increases from 0.173 to 0.4365, when Re rises from 2500 to 25,000. If we were to use Equation [32] up to values of Re = 25,000 we should get a coefficient of heat transfer more than eight times too small.

While Nusselt's theory, represented here by Equation [32], leads to the conclusion that very long tubes would not be favorable because the film becoming thicker toward the lower end, the transmission of heat would be diminished, Equation [33] shows that long vertical tubes may be suitable, because the great velocity of the water film at the lower end and the considerable thickness of the film cause turbulence and hence a better heat transfer. However, the middle part of such tubes, with a comparatively thick, but not yet turbulent, film, will counteract this effect to a certain extent.

Assuming a critical Reynolds number $(\mathrm{Re})_c = 1600$ and using the analogy between the pressure drop of a layer in turbulent motion and the heat transfer between a fluid and a wall, Colburn derived the dimensionless relation

$$\alpha_m \left(\frac{\eta^2}{g\rho^2\lambda^3}\right)^{1/3} = \frac{\mathrm{Re}}{22(\mathrm{Pr})^{-1/3}[(\mathrm{Re})^{0.8} - 364] + 12{,}800} \qquad [34]$$

in which g = the acceleration of gravity

ρ = the density of the fluid

$\mathrm{Pr} = \eta c/\lambda$ = the "Prandtl number" (c = specific heat).

In the same paper Colburn has also derived a dimensionless equation that contains the height h of the cooling surface. As it is more complicated, I shall not reproduce it. But at least I should not like to omit one point of Colburn's explanations, i.e., that the transition from laminar to turbulent motion of the film could occur even at Re < 1600. I do not know the reasons that led Colburn to this assumption, but it seems probable to me because the steam flow is agitating the film at the free surface where its velocity is much larger than the mean velocity w_m, used in the calculation of $(\mathrm{Re})_c$. On the contrary, the troubles of flow in tubes arise from the wall, where the velocity is small. Thus, Reynolds' critical number may be much smaller than one would expect on the basis of the analogy to flow in tubes, "analogy," it must be remembered, not being the same as "physical similarity," a distinction often overlooked.

In any case turbulence of the fluid film will considerably increase the rate of condensation. The best effect, it is true, would be obtained, if drop-wise condensation would be continually enforced. Therefore, it will be worthwhile also to treat this kind of condensation briefly in a more quantitative manner.

VII—DROPWISE CONDENSATION CONSIDERED MORE QUANTITATIVELY

In dealing with dropwise condensation we start with the present results of experiments, inasmuch as the theoretical funda-

[17] E. F. M. van der Held, *Physica* I, vol. 12, 1934, p. 1153.

[18] Dr. Othmer, after one of my lectures, kindly showed me his thesis of 1927 in which this is clearly stated.

[19] C. M. Cooper, T. B. Drew, and W. H. McAdams, *Industrial and Engineering Chemistry*, vol. 26, 1934, p. 428.

[20] C. G. Kirkbride, *Industrial and Engineering Chemistry*, vol. 26, 1934, p. 425.

[21] A. P. Colburn, *Industrial and Engineering Chemistry*, vol. 26, 1934, p. 432.

mentals are not as yet established. In so far as I am aware, the behavior of superheated steam, condensing in drop form, has not yet been studied. As a mere conjecture I suggest that a kind of *Leidenfrost* phenomenon, that is, the formation of a steam envelope around the drop, might be able to retard the dropwise condensation of superheated steam.

As to saturated steam, Schmidt, Schurig, and Sellschopp[2] in their experiments on pure dropwise condensation obtained coefficients of heat transfer $\alpha = 30{,}000$ to $40{,}000$ kcal per sq m per hr per deg C (referred to the cooling surface), which may be compared with 6000 kcal per sq m per hr per deg C in film condensation. I omit all of the subsequent researches and proceed at once to the latest ones known to me, i.e., the experiments carried out at the Massachusetts Institute of Technology by Nagle, Bays, Blenderman, and Drew.[6] These researchers, working with steam, which was practically at rest, found that the temperature of their chromium-plated copper tube and the condensing rate increased almost without interruption during the first 55 hours of operation, which they attributed to the spread of dropwise condensation. Only when the rate of condensation was raised by 50 per cent did the state remain constant, making reproducible measurements possible. These led to rates of 208,800 to 461,000 kcal per sq m per hr (corresponding to 77,000 to 170,000 Btu per sq ft per hr), and to a coefficient of heat transfer α practically constant, the deviations being of the order of ± 10 per cent. Their mean value of α amounts to 68,300 kcal per sq m per hr per deg C or 14,000 Btu per sq ft per hr per deg F, while the calculation according to Nusselt's theory might show a decrease of α from 4640 to 3540 kcal per sq m per hr per deg C (or from 950 to 725 Btu per sq ft per hr per deg F. Thus, the M.I.T. experiments led to values of from 14.7 to 19.3 times those for film condensation.

These results surpass by about 100 per cent those on the coefficients of heat transfer observed by E. Schmidt and his coworkers. But above all, the independence of this coefficient as regards the cooling energy, if this result should find further verification, seems to have an importance not noticed even by the observers. Indeed, I think, this result might be a first step, missing at the present time, in a theory of dropwise condensation, as a counter-part of Nusselt's water-film theory. On the basis of this result of the experiments, I have conceived the following idea:

The extraordinary intensity of dropwise condensation is caused by the direct contact of the dry cooling surface and the hot steam streaming to it. The particles of steam are held fast on the surface, without, however, forming a coherent film that would, as we have seen, offer a considerable resistance to heat transmission. On the contrary, they form droplets at once and immediately free the surface. This can be considered as being covered by a very thin layer of steam or water *in statu nascendi*, which continually and quickly varies in thickness from 0 to δ, and rolls itself together to form droplets, being built up again by fresh steam. If the kinds of surfaces and steam are given, the average thickness of this layer will depend principally upon the behavior of the nuclei (initiating the condensation) and of surface, but slightly upon the rate of cooling, as seems to result from the M.I.T. experiments. This seems to me to result from the fact that in every case drops of certain size are developed by a layer of a certain thickness, but are developed in shorter intervals and more quickly if the cooling is augmented. For, if the temperature drop across the layer increases, a greater cooling effect will be carried into and through the layer, more steam will be brought to it, and more drops will be formed, all without changing the average thickness of the layer.

Although a certain difficulty may be seen in the assumption that across a layer of this kind the temperature drop should be the same as across a Nusselt layer, and though at present, we do not yet know whether this layer consists of steam or water or mist, the results of experiments enable us to compute two limiting values for its average thickness δ. From the basic equations of heat transfer

$$q = \alpha\Theta \qquad [35]$$

and of heat conductivity through a plane layer

$$q = \lambda\Theta/\delta \qquad [36]$$

Θ being the difference between the temperatures of the steam and of the cooling surface, we get the well-known formula

$$\delta = \lambda/\alpha \qquad [37]$$

Using the measured value $\alpha = 68{,}300$ kcal per sq m per hr per deg C and assuming a mean steam layer (with $\lambda = 0.02$ kcal per m per hr per deg C) we come to

$$\delta = 0.02/68{,}300 \approx 0.3 \times 10^{-6}\text{m} = 0.0003 \text{ mm}$$

corresponding to about 1000 diameters of a molecule, this being a very thin layer, since the molecules have a great distance in the steam. The actual thickness δ_1 of the layer will be larger, since the thickness varies between 0 and δ_1, the duration of these two thicknesses not being known.

If, on the other hand, the layer should consist of water ($\lambda = 0.587$), its mean thickness would be

$$\delta = 0.587/68{,}300 \approx 9 \times 10^{-6} \text{ m} = 0.009 \text{ mm}$$

In any case the thickness δ may be of the order of magnitude of 0.001 mm. According to this, my conception consists in supposing a sort of film like Nusselt's, but with the following essential differences:

Nusselt's film is a stable layer of continually increasing thickness. On the contrary, the layer suggested in this lecture is unstable and changes quickly, but is of constant mean thickness. The thickness of Nusselt's film depends on the intensity of the cooling, the height of cooling surface, etc. The thickness of the layer we think of depends on the properties of the surface, the purity of steam, etc.; and the rapidity with which new layers originate depends on the intensity of cooling, etc.

In following out these ideas, the independence of the heat transfer coefficient α of the cooling rate should first be examined in varying the conditions and in extending the limits of observation. Presumably, the limit of supersaturation, known as the Wilson line will set a lower limit, permitting the smallest possible drop radius for a given surface tension of the fluid against the steam. Thereupon, the growth of drops until they begin to roll down should be measured, perhaps by microscope and high-speed camera. This would give the number of droplets. Of course, the rolling and uniting of drops should also be observed optically and should be taken into consideration, an extensive program, but probably worthwhile.

Not only the difficulties of the scientific problem, but also the practical importance of enforcing dropwise condensation which is up to 20 times more efficient than film condensation, cannot be overestimated. A first advance into this region has been made by W. M. Nagle,[22] working at that time at the Massachusetts Institute of Technology with a United States patent relating to the addition to the steam of certain agents as drop promotors. In this direction certainly noteworthy practical successes are to be expected.

Finally the author wishes to express his sincere thanks to the societies, colleges, and firms, who by their kind invitations, gave him the opportunity of delivering these lectures.

[22] W. M. Nagle, U. S. Patent No. 1,995,361, March 26, 1935.

ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

BECAUSE the editor of this section, who has abstracted the articles that have appeared in it since the establishment, in 1912, of the "Foreign Review" as it was then called, is on leave of absence, space devoted to the abstracts has been reduced.—EDITOR.

AIR MACHINERY

Estimation of Slip in Air Compressors

THE estimation of slip in air compressors by altering the clearance volume is undertaken by the author by means of a study of the effect of clearance volume on volumetric efficiency of a compressor. Theoretically, as shown by the author, the volumetric efficiency for any one delivery pressure lies in a straight line which commences at unity when plotted to a base of clearance volume.

Tests with a view to estimating the slip at various pressures were carried out on a small single-acting commercial compressor and from data obtained the free-air discharge per stroke, the discharge efficiency, and the value of the expansion exponent were determined. The method of operation is set forth in detail in the original article.

The procedure may be briefly stated, as follows: Test the compressor in the normal way at different pressures, measuring the air discharge after compression, then alter the clearance till it is about doubled and carry out identical tests. The clearance volume may, of course, be altered temporarily by placing a distance piece between the cylinder and the cylinder head. Plot the discharge or volumetric efficiency to a base of clearance volume and determine the slip in the manner explained.

One advantage of this method is that only one air-measurement nozzle is required, and this should prove attractive to makers who do not carry a duplicate set of standard air-measurement nozzles. Accepting the slip values given as typical, compressor designers, knowing as they do average expansion exponents of many types of compressors, should be able to estimate with a fair degree of accuracy discharge efficiencies at any delivery pressure and clearance volume. (Robert Thomson, *Engineering*, vol. 142, no. 3682, Aug. 7, 1936, pp. 138–139, 7 figs.)

ENGINEERING MATERIALS

Wall-Thickness Sensitivity of Metals and Alloys

THE term "wall-thickness sensitivity" has been created as a result of numerous investigations on cast iron and usually means sensitivity toward variations in velocity of cooling and changes in structure (grain size, particle size) and properties determined thereby.

The wall-thickness sensitivity of metals and alloys can be expressed numerically by representing the functional relation between property F (which in the majority of cases is tensile strength) to the wall thickness d by a hyperbolic

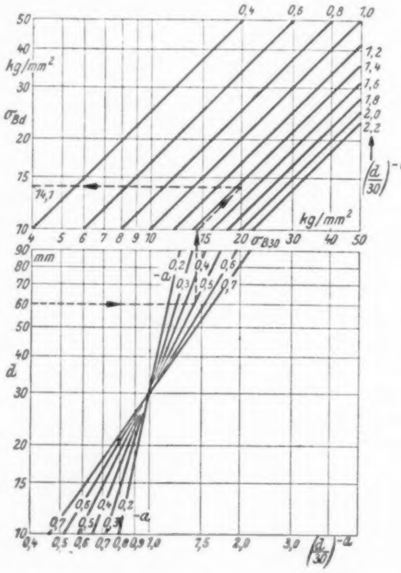


FIG. 1 NOMOGRAM FOR THE DETERMINATION OF TENSILE STRENGTH IN WALL THICKNESS FROM 10–90 MM IN DIAMETER

curve of the shape $F = k/d^a$ where k and a are constants. In a logarithmic form this equation has then the following form

$$\log F = -a \log d + \log k$$

If the functional relationship between tensile strength and wall thickness of a metal or an alloy be plotted on a double logarithmic scale a straight line is obtained. The constant a gives an inclination of this line and may be used as a numerical expression of the wall-thickness sensitivity. The constant k is a numerical expression of this property for $d = 1$.

The author's tests dealt chiefly with the influence of composition, heat-treatment, melting, and teeming practice. The tests carried out heretofore have shown that all cast alloys are more or less sensitive in this respect. From a practical point of view the most important fact is that the wall-thickness sensitivity may be reduced in several ways. It is, however, necessary to determine, if possible, for every kind of alloy, the relation between wall-thickness sensitivity and the composition and other variables of the alloy. In this way the machine designer would have a means to determine it, using as a basis, in the case of cast iron, for example, the strength of a 30-mm. bar. Then by means of the equation

$$\sigma_d/\sigma_{30} = (d^a/30)$$

the strength in other wall thicknesses could be computed. Such a computation would be particularly assisted by using a nomogram, such as shown in Fig. 1.

This nomogram is based on a cast-iron bar 30 mm in diameter, having a tensile strength of 20 kg per sq m, and a wall-thickness sensitivity, such that $a = 0.5$. Let it be assumed that it is desired to determine the strength of a bar 60 mm in diameter. This is done in the following manner:

$$\sigma_{60}/\sigma_{30} = (60/30)^{-0.5} = 2^{-0.5}$$

$$\sigma_{60} = 20/2^{0.5}$$

$$\log \sigma_{60} = \log 20 - 0.5 \log 2 = 1.30103 - 0.15052 = 1.15051$$

$$\sigma_{60} = 14.14 \text{ kg per sq mm}$$

The value given by the nomogram is in good accord with the value calculated. (E. Söhnchen and E. Piwowarsky in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 80, no. 31, August 1, 1936, pp. 933–936, 13 figs.)

HYDRAULIC ENGINEERING

Cavitation and Surface Tension

IN connection with the Zuyder Zee reclamation scheme rapid erosion of impellers was found to be caused by cavitation. In some pumping stations cavitation was found to take place when the pumps were operating under normal conditions of delivery and suction. In this connection a contribution by F. K. T. van Iterson, published in the Proceedings of the Royal Academy of Sciences at Amsterdam, is cited.

Tests were made both with clean water taken from the town supply and with water contaminated with mud.

Professor van Iterson concluded from his experiments that the erosion caused by surface cavitation is due to the effect of surface tension acting on the air bubbles, a force generally neglected in hydromechanics, because of its small magnitude, which is of the order of 0.075 gram per centimeter. The work demonstrated that air globules tend to form on the walls or boundary surfaces, where the absolute pressure has a minimum value, and that release of the air in water is influenced by the condition of the boundary surfaces—in a manner resembling that of catalysts in chemical reactions. This was demonstrated by the experimental observation that excess of air or gas in the water was not easily released or freed in the presence of clean surfaces, while it was facilitated by adding to the surface a substance that acted as a collector of the bubbles, such as are employed in flotation processes. Suitable substances for this purpose appear in general to be products containing at least 16 atoms of carbon. When account is taken of this factor, the results obtained give support to the view put forward that air globules probably originate at the common time of contact of a boundary surface, a suitable collector, and the liquid.

It was also found in the course of the tests that with clean water the surface cavitation commences when the radius of a bubble is 0.0001 in. (0.0003 cm), and that globules of a diameter less than 0.00024 in. (6 microns) can exist only in clean water. These bubbles increase rapidly in size as the effective pressure decreases in value, but they always remain small in magnitude during the phenomenon of cavitation. When, however, the water is contaminated with oil or organic matter, a foam is formed by numerous small bubbles which still remain small and isolated, particularly if the globules are situated in the boundary layer of the moving liquid. In these circumstances a quasi-chemical combination occurs between the water and metal, and bubbles having a diameter amounting to a fraction of a millimeter are slowly entrained in the boundary layer, though some of the globules in the region of the turbulent flow are sheared (cisaillé) by the fluid in motion.

The effect of the presence of oil is also discussed. (*Engineering*, vol. 142, no. 3680, July 24, 1936, pp. 95–96)

RAILROAD ENGINEERING

Streamlined Locomotives

THE two articles abstracted deal with the locomotive recently built in the shops of the London and Northeastern Railway from designs prepared by Sir Herbert Gresley, which do not resort to streamlining. An editorial in the July 3, 1936, issue of *The Engineer* says:

Streamlining may or may not have real advantages besides its appeal to the imagination of passengers, who may prefer, for no scientific reason, to travel in a train hauled by a peculiar looking engine. While, therefore, there may be something to be said from the revenue-earning point of view for the covering up of locomotives in very expensive and equally ugly envelopes, what actually is to be gained is, as the editors have suggested before, still a doubtful quantity. The fact that Sir Herbert Gresley has omitted it from the "Green Arrow" whilst adopting it for his new versions of the "Cock o' the North," suggests that he recognizes that it is only for special services, and perhaps on special routes, that the expense of external streamlining is justified, unless it be looked upon rather as a means of keeping steam from obstructing the driver's view than as a means of reducing air resistance.

In another editorial dealing with streamlined locomotives, *The Engineer* comes to the conclusion that in relatively small high-speed vehicles or trains of two or three coaches, it may be worth while, whereas it is of still doubtful use in the ordinary type of train, hauled by the ordinary type of locomotive, and of necessity traveling at very variable speeds. The editorial says it is "still doubtful" because, although both at home and abroad a great deal is heard about streamlining and a certain amount has been done, very few reliable figures have been published. Most of the arguments are based upon wind-tunnel experiments, none of which can be regarded as conclusive. In the testing of airplane models the conditions of actual flight can be simulated with fair closeness; but the model tests of a locomotive and train can never be carried out with any approach to the conditions which prevail in practice. The only complete and satisfactory answer to the question must be sought in the comparison of the running costs of streamlined and nonstreamlined trains on identical services for a long period. Such a straight experiment is not likely to be made by the accumulation of results sufficiently numerous to allow a statistical examination to be carried out.

While such data are lacking, locomotive engineers are perfectly justified in their cautious approach to the problem. With one exception—the "Silver Link" class—there is no fully streamlined train in the kingdom, and it would seem that, in general, streamlining of locomotives is being carried out rather as a concession to popular opinion than from real conviction that it is profitable. Abroad, a little, but not much more, has been done. For example, both Henschel and Borsig have produced engines completely enveloped in a smooth integument. Unfortunately, these engines, as usually happens, are not strictly comparable with others, and their merits have to be estimated rather than ascertained by trial. M. Kandaouroff has recently given in *Le Génie Civil* an estimate of the kind, using a corresponding Nord engine as a basis of comparison. A few of the figures may be quoted. Taking the Nord engine as 100, then the consumption per gross ton-kilometer of the Borsig and Henschel streamlined engines would be 113.2 and 119.9, respectively, but speeds would be 100, 120.1, and 121.8. These figures show, indeed, that with the streamlined engines a greater speed could be attained for a smaller consumption of coal per kilometer, but they still leave us greatly in the dark, for we do not know what the consumption of the Nord engine would have been at the speeds assumed for the other engines. It must be added also that the engines are dissimilar in several critical respects. We have mentioned these estimates less for higher actual value than to illustrate the haziness which still enshrouds the economics of streamlined locomotives.

Since mention of the Prairie-type locomotive designed by Gresley has been made it may be added that it is a remarkable piece of work in certain respects and embodies a number of features either never or only sporadically used previously; the wheel arrangement of 2-6-2 is unusual in England.

Compared with the 2-6-0 class, the boilers fitted to the new engines have a combined heating surface of 3110 sq ft, against 2308 sq ft, or practically 35 per

cent more, and at the same time the grate area is larger by 47 per cent, being raised from 28 to 41.25 sq ft. Along with these changes the tractive efforts are, respectively, 30,031 lb for the old engine and 33,730 lb for the new, a difference of some 12 per cent only, thus illustrating in a marked manner the large steaming capacity available in comparison with the cylinder power. The boiler itself is like that used for the later Pacifics, those working at 220 lb per sq in. pressure, the firebox and grate being the same, while the superheater is similar. In fact, the chief deviation is in the length of the tubes, which, owing to the wheel arrangement, are shorter by 2 ft, being 17 ft in length between the sheets, comparing with 19 ft for the express engines. Comparing the 1920 design with the present, the relationship between the engine weight and tube evaporative heating surfaces is interesting. For the 2-6-0 type the weight per square foot of heating surfaces works out at 84.4 lb, and for the 2-6-2 this figure is practically the same, namely, 85.7 lb. On the other hand, the heating surface allowed per square foot of grate is 67.8 in one case and 58.8 in the other.

The wheel plan with a single-axle leading truck lends itself well to the use of three cylinders which has been adopted in this locomotive, as by it it is possible to get a particularly neat design either in three separate castings or in one of the mono-block pattern. With cylinders in line not only has the cylinder layout been greatly simplified, but all parts are considerably more accessible. (*The Engineer*, vol. 161, no. 4195, June 5, 1936, pp. 599–600, and vol. 162, no. 4199, July 3, 1936, pp. 13–14)

STEAM ENGINEERING

Tests of a 36,000-Kw Steam Turbine

RESULTS of tests carried out on a 36,000-kw steam turbine (120 kg per sq cm, 480 C), with intermediate superheating and extraction are reported. This turbine was delivered to the Witkowitzer Mining and Steel Co. and is the only steam turbine of that size in Europe operating with such pressures and temperatures. Tests were carried out in February, 1933, with and without intermediate superheating and with and without feedwater heating by extraction steam. The turbine runs condensing at a normal rated speed of 3000 rpm, and is of the three-cylinder type, the low-pressure cylinder being of double-flow design. It was built for immediate superheating up to 360 C at the inlet into the intermediate cylinder and with two extraction branches for feedwater heating, of which usually only the low-pressure extraction branch is used in service. The table in the original article gives the material used in the construction of the turbine and the number and dimensions of the stages and their distribution.

Table 2 in the original article contains the most important measurement readings. The main test, No. 1, gives a specific steam consumption of 3.22 kg per kwhr, at the generator coupling. The steam was then at 120.7 kg per sq cm abs and 477 C at the main inlet valve of the turbine; intermediate superheating took place at 350 C at the inlet to the intermediate-pressure cylinder, with 0.054 kg per sq cm abs in the exhaust branches and with condensate heating to 86.2 C by extracted steam. The specific heat consumption of the turbine was then 2477 kcal per kwhr at the coupling.

According to these figures, the thermal efficiency of the turbine under test which, when all is said, is the deciding factor for the degree of steam utilization developed by the set, amounts to 34.72 per cent when intermediate superheating and condensate heating by extraction are used and referred to the output at the generator coupling; this is a remarkably high figure for a condensing turbine plant. The thermal efficiency drops back to 33.22 per cent, that is, is reduced by 4.55 per cent, when the condensate heating by extraction steam is cut out and it drops to 32.63 per cent—that is by 6.24 per cent in all—if the intermediate superheating is eliminated. Thus, the two additional processes account for an appreciable economy in heat, and further intermediate superheating has the advantage of reducing by about 6 per cent the moisture content of the exhaust steam.

The thermodynamic efficiency of the Curtis wheel for all tests was between 60 and 62 per cent (there is here a certain element of uncertainty). The reaction part of the high-pressure cylinder with a Parsons' number of about 3250 works out to an internal efficiency of about 80 per cent. The internal efficiency of the low-pressure cylinder with intermediate superheating amounts to about 73.5 per cent.

A thermodynamic efficiency of about 76 per cent was determined for the whole turbine operating with intermediate superheating and referred to the power delivered at coupling (Table 3) (because of lack of space the tables are not reproduced). In considering this value, it should be remembered that, here, the adiabatic drop is the sum of the three partial drops in the high-, intermediate-, and low-pressure cylinders. Now, the total adiabatic output is the greater, and the resulting thermodynamic efficiency of the turbine the smaller, the more the total heat drop is subdivided. This is seen by a comparison of the efficiency given for the whole turbine by test 2 in Table 3, with the figures given in Table 4 for the same tests; the values of Table 3 are somewhat lower than those of Table 4 because, in the latter case, the total drop is only subdivided into two partial drops as compared to three in Table 3.

Usually, the overall efficiency of a purely condensing turbine is referred to the total adiabatic heat drop from live-steam conditions down to vacuum. This is not possible, in the present case, because of the intermediate superheating. If the heat regained in the high-pressure stage owing to the nonadiabatic expansion is taken into account and if the intermediate and low-pressure stages are taken in one, an overall efficiency of the turbine of 80 per cent, referred to coupling output, is reached. (E. Josse in *Brown Boveri Review*, vol. 23, no. 5, May, 1936, pp. 131–136, 4 figs.)

WELDING

Welding Metals Without Fusion by Molecular Shock

THIS method was developed by Antonio Longoria, of Cleveland, Ohio, and is said to be successful. It is said that two pieces of 28-gage stainless steel have been welded at a temperature not exceeding 700 F and the weld showed a tensile strength within 1/10 of 1 per cent of that of the base metal. It is also stated that Longoria has welded 16-gage galvanized-steel sheets at the rate of 64 ft per min. No pressure is required on pieces to be butt-welded. The edges are simply sheared and placed together before running through the equipment which does the welding. The underlying theory is that metals like all matter are composed of molecules held together by molecular attraction which involves electric charges on the molecules. Longoria reasoned that if it were possible to break down this molecular bond in two pieces of metal while they are in contact, then they would weld together without fusion. This bond is said to be broken by the proper application of high-frequency electric currents. Photomicrographs of welded material after etching are shown in the original article. (A. H. Allen in *Steel*, vol. 98, no. 25, June 22, 1936, pp. 34–36, illustrated.)

LETTERS AND COMMENT

Brief Articles of Current Interest, Discussion of Papers, A.S.M.E. Activities

Herschel and Niagara

[In our issue of September, 1936, so largely devoted to Niagara Falls, space did not permit mention of a long list of prominent engineers who contributed to the hydroelectric development of the Falls. Among these was Clemens Herschel, an eminent civil and hydraulic engineer who was well known for his work on the Holyoke testing flume, and who served as hydraulic engineer for the Niagara Falls Power Company. By coincidence, Mr. Herschel's son, Mr. Winslow H. Herschel, sent us, when the September issue was on the press, a copy of a letter from his father which we have his permission to publish. Although a personal letter, its spirit is so characteristic of the man who wrote it that all who knew him will find pleasure in reading it. We share the opinion of Mr. Winslow H. Herschel that no one will take offense at frankness:—Editor.]

New York, N. Y., April 13, 1928

Dear Winslow:

In reply to your letter of 12th:—When Nia. Falls Power Co. plant No. 1 was begun, it was a novel undertaking. The Co. had a lot of foreign advisers, who knew ***nothing*** of the practice of water power construction and operation. Your father, on the contrary, had just finished 10 years of hard work at it, in Holyoke. One fine day, Lord K. wrote a little squib of a note, (I saw it once, and it looked like a lady's invitation to tea) to Prof. Unwin, and suggested wouldn't the water issuing from the Nia. tail-race tunnel, into the air as designed, come out in pulsating discharges—by jerks, as it were—and thus cause damage, upstream to the machinery, and perhaps downstream also, or to the tail-race masonry. With the respect, or deference, yea reverence, that Englishmen have for other Englishmen, a peg higher than themselves in the social scale, this immediately captured the whole flock of British consultants (I forget their names) and they wrote a formal letter to the Co. in New York giving vent to doubts and fears, but careful to assert, or attempt to prove, ***nothing***. I had not the fear of titles, etc. before me, and when this letter was submitted for my examination and report, I pointed out that it merely questioned, and doubted, and generally tried to throw a scare, and amounted to nothing of a positive nature. The matter was of *exceeding importance*. I may say at once that in my opinion, had these consultants been heeded, the enterprise would have failed of completion.

It concerned the location as regards "elevation," usually called grade, of the whole tail race. The English consultants wanted to lower, parallel to the location as then designed (and later built) the whole tail race, 40 feet; so as to have the discharge "submerged." But such is the formation of the banks of the Niagara river, strewn with blocks of the cliffs forming it, of huge dimensions, as big as a small house and less, that no way of building in them for 40 ft below water, that I ever heard of up to that time, or to date, was or is yet known to me, and to attempt it, would have spelled financial bankruptcy, in my opinion.

In consideration of all the foregoing, the Co. sent me to London to consult with the consultants. I went, staid a week, and came home on the steamer I went over on. Meantime, however, I had had one meeting with the British consultants. (Lord K. by the way, was not at this meeting.) To use a slang expression, I "mopped the floor" with those learned English engineers, professors, etc., being at the time young and impudent. But then, I knew, from my life's work, what I was talking about, and they did not, to put it bluntly. So that, after I got home, I never heard anything more of a proposition to make the tail-race tunnel so as to discharge 40 ft below the level of the Niagara River.

By the way, the ogee form of discharge built, and the construction details of it, I have always considered one of my successful pieces of engineering work; built, moreover, under difficult circumstances, and exposed to very great strains in service.

Now as a punishment for making me write this long letter, I am going to ask you to send me a typewritten copy of it.

Affectionately your father,
[Signed] C. H.

Graduate Engineering Study

To the Editor:

Your issue of August, 1936, carries a review of the article "Educational Qualifications in the Engineering Profession" which appeared under the authorship of Andrew Fraser, Jr., in the *Monthly Labor Review*, published by the United States Department of Labor. It is entirely proper that this review should have been published in the various technical and professional engineering journals, for the study of the engineering profession on which it was based promises to be—in fact, this first installment of the results of the survey shows clearly that it is—a significant contribution to our knowledge of the circumstances and the education of the personnel of the profession. No such comprehensive study, as to numbers canvassed, has been attempted previously, so far as I know.

Results of this survey will be quoted widely as an authentic and accurate picture of those phases of the profession that the assembled data cover. It is highly important, therefore, not only that the original data be representative of the bulk of the profession and of its several divisions, but also that the analysis and interpretation of the data be accurate.

It is for this reason that I am venturing to call attention to a particular phase of the analysis and interpretation as given by Mr. Fraser. The following statement is there made: "Graduate study in engineering does not appear to be of any considerable importance as a prerequisite to practice in the engineering field." This is followed by a summary of proportions of graduates in the principal professional divisions who hold master's degrees. Presumably these ratios are based upon analysis of returns from all groups reporting, regardless of age or duration of period since graduation from college.

It happens that for the past two years a comprehensive survey of the status of graduate work in American engineering colleges has been in progress under the

joint direction of a committee of the Society for the Promotion of Engineering Education and the United States Office of Education. Part of the results of this survey appeared in the *Journal of Engineering Education* for December, 1935. A final, comprehensive report is now in the hands of the Public Printer. One purpose of this survey was to learn the trends of graduate work in engineering in recent years. The results indicate a rapid growth during the past 15 years, as the following tabulation indicates:

Academic years	Total number of students enrolled in graduate work in engineering (U. S. A.)	Total number of advanced degrees in engineering conferred
1921–1922	368	178
1925–1926	1014	267
1930–1931	2939	418
1931–1932	3961[1]	1002
1933–1934	2756[1]	1197

[1] The apparent shrinkage in enrollment from 1931–1932 to 1933–1934 is due to the fact that up to and including 1931–1932, when the statistics were compiled by the Office of Education, all graduate students enrolled in engineering colleges, schools, and departments were counted. Since some of the separately organized colleges of engineering and some of the schools of engineering of universities reported students enrolled in them in such curricula as chemistry, physics, architecture, and the like, the figures were inflated prior to 1933–1934. For that year, however, the figures are accurate. All American engineering institutions offering graduate courses are included in them.

The tabulation and other data gathered in the survey indicate a rapid growth in graduate study; in enrollments there was a gain of nearly eight-fold between 1921–1922 and 1933–1934; while in number of graduates of advanced courses the gain was nearly seven-fold in the same period. At the present time the number of graduate students of engineering is roughly one fourth the number of bachelor's degrees conferred during the preceding year, and the number of the master's and doctor's degrees conferred in any year is roughly one eighth the number of bachelor's degrees conferred in that year. If the data that the S.P.E.E. committee has been able to secure from other than its own questionnaires are reliable as to other professions, it appears that engineering ranks second only to chemistry in the number of doctor's degrees conferred annually in the various divisions of the physical sciences. It is impossible to learn where it stands in relation to other fields in the proportion and number of master's degrees conferred, although the rank of engineering is undoubtedly very high in the list.

It seems proper, therefore, to question whether it is correct to infer from the data which were obtained in the Labor Department's study that graduate work in engineering is of relatively little importance, at present, as a prerequisite to practice.

The fault in this interpretation appears to lie in the fact that the analysis was based upon the entire group of engineers canvassed, regardless of age. Such an analysis would assume the conditions in the engineering profession to be static, in so far as education and training are concerned. It is evident from the trends indicated by the S.P.E.E. Office of Education study, and as well-informed engineering educators know, that the trend toward graduate work in engineering education has been a strong one in recent years; it is also clear that industry and the profession at large are beginning to look upon graduate work—some divisions of the profession have already, in fact, come to look upon it—as a highly desirable preparation for certain types of positions and for certain fields of work. The attitude of the profession toward the preparation of its recruits seems to be undergoing a change in that greater weight is being given not only to sounder training in the fundamentals of engineering science, but also to more extended training in its higher phases.

The foregoing discussion of the results of the Labor Department's study is given not only because of its bearing upon the matter of graduate work alone, but also because the same condition, namely, changes of conditions in the profession as represented by differences of results of studies when different age groups are analyzed, may affect other aspects of this or similar investigations. It may be hoped that the Labor Department could amplify its results in terms of studies of the several age groups among those who supplied information.

H. P. HAMMOND.[2]

[2] Chairman, Committee on Graduate Study, Society for the Promotion of Engineering Education.

Flow Through Orifices in Series

TO THE EDITOR:

Several interesting questions arise in the consideration of the paper.[3] Perhaps the most important is the effect upon the phenomena under consideration of the distance between the two nozzles. What space must be provided to make certain that the fluid is throttled through the first nozzle? Under what circumstances is the enthalpy at the entrance to the second nozzle really equal to that at the entrance to the first?

[3] "Fluid Flow Through Two Orifices in Series," by Milton C. Stuart and D. Robert Yarnall, MECHANICAL ENGINEERING, August, 1936, pp. 479–484.

The graphical method of determining the intermediate pressure becomes much more difficult if any of the kinetic energy from the first expansion continues to exist as such. It is of considerable interest, therefore, to know under just what circumstances one is justified in assuming that the velocity has been completely reconverted into heat.

Stodola[4] presents a brief discussion of the flow of steam through discontinuous nozzles, but he makes no mention of the aspects which the authors have considered.

The authors' Fig. 11, showing the critical-pressure ratio for saturated steam as a function of the pressure, is interesting and the writer would like to know how the values for this curve were obtained.

It is probable that supersaturation plays an important part in the expansion of saturated steam through nozzles. For this reason the critical-pressure ratio can most probably be calculated, as for superheated steam, from the familiar relationship

$$\left(\frac{p_2}{p_1}\right)_{cr} = \left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

where k is the index of isentropic expansion.

For superheated steam, the variation of k with pressure and temperature is relatively large. Keller[5] has found that k ranges from a minimum of 1.26 at 1470 lb abs, 932 F, to a maximum of 1.34 at 2060 lb abs, 752 F. In most engineering computations k is assumed to have the value 1.30 which may thus be in error by ± 3.1 per cent.

The function $\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$ varies from 0.5531 with $k = 1.26$, to 0.5386 with $k = 1.34$. With $k = 1.30$, the function has the value 0.5457. The possible error is thus ± 1.6 per cent.

In this connection[6] it is interesting to

[4] "Steam and Gas Turbines," by A. Stodola, McGraw-Hill, New York, N. Y., 1927, vol. 1, p. 105.

[5] "The Adiabate Exponent k for High-Pressure Superheated Steam," by C. Keller, *Escher-Wyss News*, July-August, 1934, vol. 7, no. 4, p. 104.

[6] "Heat Power Engineering," by W. N. Barnard, F. O. Ellenwood, and C. F. Hirshfeld, John Wiley and Sons, Inc., New York, N. Y., 1933, vol. 2, p. 11.

note that, for values of k from 1.20 to 1.40, $\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$ is virtually a linear function of k.

The saturated-vapor portion of the authors' Fig. 12 is likewise of interest, and the writer would like to know how these values were obtained.

The authors mention the fact that variations in the form of nozzles A and B should react to give changes in the intermediate-pressure curves. The use of sharp-edged orifices might lead to interesting variations, since the flow of steam through such orifices does not reach a maximum value when the back pressure becomes equal to the critical value. On the contrary, the flow continues to increase as long as the back pressure is decreased.

The writer would like to raise the question of precise terminology in connection with the authors' use of the term *orifice* for rounded-approach obstructions in a pipe line. Would it not be better to apply the term *nozzle* to such devices, and to restrict the term *orifice* to sharp-edged obstructions?

JOHN I. YELLOTT.[7]

TO THE EDITOR:

My brief comments on this paper[3] will not deal with the thermodynamic analysis, which is presumably correct, or even with the conclusions developed, which are definitely interesting. I shall view this paper, rather, as an object lesson in the psychology of engineering.

We here see, again, the sort of thing which has happened so often in the history of engineering. A new and valuable device has been developed, largely by engineering intuition, and then the theory worked out *post-facto* to satisfy the curiosity of all concerned and lay a rational foundation for future modifications and new applications. This condensate-draining device has been implicit for a long time in the known laws of thermodynamics. Yet it remained invisible to those most closely associated with that science.

It is a safe guess that steam has many other useful tricks "up its sleeve" and that their progressive revelation will depend as much upon the creative imagination of engineers as upon their knowledge of thermodynamic fundamentals. It is my expectation that the next five or ten years will see many new and ingenious applications of the properties of fluids, particularly of steam and water. Some of these will undoubtedly have great practical importance.

The ideal contributor to such progress will be the engineer who rounds out the imagination and resourcefulness of the old-time Yankee inventor with a modern technical understanding of the behavior of water, steam, and gas. In my opinion, the engineering schools can perform no greater service than to fan the pioneering spark in their students while drilling them in the hard logic of engineering.

PHILIP W. SWAIN.[8]

TO THE EDITOR:

Inasmuch as this paper[3] discusses an element used to control the flow of a fluid in its stages between liquid and vapor, it is of direct interest to the designer of machinery handling fluids.

The writer, in particular, welcomes Figs. 11, 12, and 13 giving the critical-pressure ratio and the rate of flow through ideal nozzles of saturated liquid water and saturated water vapor for all pressures. While the nozzles and blades of steam turbines generally operate with superheated steam or with, at the most, 12 per cent moisture, and thus cover a fairly narrow range of critical-pressure ratios (between 0.57 and 0.60), the saturated-liquid curve, that is, considerably higher values of the critical-pressure ratio are reached in the orifices regulating the drainage of moisture from low-pressure stages and sometimes in labyrinth packings and other leakage seals.

In a paper entitled "The Leakage of Steam Through Labyrinth Seals,"[9] only the gaseous phase of steam was considered. The paper by Stuart and Yarnall shows principally how to calculate the integral $\int vdp$ on which basis (refer to Equation [19] of the aforementioned paper) a simple theory for the leakage of saturated liquid water or compressed liquid water through labyrinths can be developed.

ADOLF EGLI.[10]

TO THE EDITOR:

Answering the first of Professor Yellot's queries, reference to Fig. 7 in the paper shows the device which incorporates the two orifices in series, from which it is seen that the space between the two orifices is quite large and that the direction of the velocity is changed, so there is no doubt as to the reduction of the intermediate-chamber velocity to practically zero, and thus a return to the initial enthalpy.

All values of the critical-pressure ratio throughout the paper were determined by computing the flow characteristics of the nozzles, plotting these characteristics similar to those of Figs. 9 and 10, and establishing the critical pressure as the downstream pressure at which a maximum value of M/A occurs. For the saturated liquid and the subsaturated liquid, computations were made by a step-by-step arithmetic computation, using the method of the formula at the top of page 483. For the saturated-vapor portions the flow characteristics were computed by the usual constant-entropy method for nozzle flow.

No values of the critical-pressure ratio were obtained from the formulation involving k, since k is quite variable, as could be shown by computation from the relation between k and the critical-pressure ratio.

Not only would the supersaturation phenomena influence the flow with vapor, but more important, perhaps, the flow of the saturated liquid would be largely conditioned by the two-phase flow phenomena, which takes account of the fact that in the flow of a mixture of liquid and vapor the two phases flow at different velocities. This is discussed by Barnard, Ellenwood, and Hirshfeld[11] and opens up a field of research to which we confidently anticipate Professor Yellott will richly contribute, as he has done in the supersaturation field.[12]

The paper as presented is restricted in its scope to the ideal processes within the device; research will discover departures from these ideal processes, which departures would include the effects of supersaturation, two-phase velocities, friction, and orifice form.

The authors freely accept the desirability of the terminology mentioned in Professor Yellott's last paragraph which applies the term "nozzle" to all passages having a well-shaped entrance producing streamline flow to the point of the critical pressure. The term "orifice" was used as a generic term in the paper to include

[7] Assistant Professor of Mechanical Engineering, Stevens Institute of Technology, Hoboken, N. J. Jun. A.S.M.E.

[8] Editor, *Power*, McGraw-Hill Publishing Co., New York, N. Y. Mem. A.S.M.E.

[9] "The Leakage of Steam Through Labyrinth Seals," by Adolph Egli, Trans. A.S.M.E., vol. 57, 1935, paper FSP-57-5, pp. 115–122.

[10] Experimental Division, Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.

[11] "Heat Power Engineering," by W. N. Barnard, F. O. Ellenwood, and C. F. Hirshfeld, John Wiley and Sons, Inc., New York, N. Y., 1933, vol. 2, p. 22.

"Supersaturation and the Flow of Wet Steam," by G. A. Goodenough, *Power*, Oct. 4, 1927, p. 511.

[12] "Supersaturated Steam," by John I. Yellott, Jr., Trans. A.S.M.E., vol. 56, 1934, paper FSP-56-7, p. 411.

all passages which may be considered in the device.

Mr. Egli's suggestion of the use of the methods of the paper in the field of steam turbines is appreciated.

The discussion by Mr. Swain might be emphasized. It cannot be stressed too greatly by the schools that the tools found in the theory are applicable to real, live, everyday problems. Many students can follow the procedures outlined in textbooks, but more of them should develop the habit of applying the tools of engineering to new and interesting problems that are not yet textbook material.

M. C. STUART.[13]
D. ROBERT YARNALL.[14]

Suspended Solids in Foaming and Priming

TO THE EDITOR:

It has been with a great deal of interest that I have followed Dr. Foulk's work[15] on foaming and priming, and I have a feeling that now he is beginning to realize that there is really more to it than was thought at the start.

I have had an opportunity for a score or more of years to watch the operation in actual practice, and then check up on chemical conditions with so many kinds of waters, that it is rather interesting to note a great number of cases which practically support the ideas embodied in this paper. The most important feature, however, is the realization that we have still much to learn.

It is true that solid matter does not always increase foaming. Material in a granular form and in a flocculant, coagulant form seem either not to affect it at all, or to decrease it. Old scale can be disintegrated with a boiler in operation, and rarely does this disintegrating scale affect steaming conditions.

It is also true that the use of sodium aluminate and the phosphates has been attended with a noticeable decrease in foaming tendencies owing to the physical condition of the precipitates which are formed.

The action of magnesium hydrate in reducing foaming or priming would be explained by the fact that it also has coagulating properties. The literature contains many references to the coagulating effect of magnesium in water softening when it exists in relatively large quantities as the bicarbonate; and if sufficient magnesium exists in the raw water, a coagulant can sometimes be dispensed with without impairing the efficiency of settling out.

Relative to the difference in foaming properties when calcium and magnesium salts enter a highly alkaline water, as compared with the reverse of this condition, experience in a plant in Minnesota may be cited. This plant had operated with a highly mineralized water treated with a Zeolite softener, but found it was impossible to operate satisfactorily due to the rapid increase in soda salts. A hot-process softener was installed in place of this, and the water softened with soda ash only to remove sulphate of lime. At the outset much carbonate remained in the water when it entered the boiler, and the change was made from Zeolite to the hot process without taking the boiler out of operation or changing the water in it. Serious foaming was noted almost immediately, as the partly treated raw water entered the highly concentrated mixture of caustic and carbonate. After the boiler had been drained and the water changed no trouble in the way of foaming has occurred since.

Tannins also, owing to their effect in producing certain physical types of precipitates, seem to be effective in reducing foaming while apparently increasing the solid material in suspension.

Little by little the information we are gathering from different sources is going to fit into an intelligent scheme, but the important thing about what is being done now is this tendency to impress us all with how little we know about the subject.

DUDLEY K. FRENCH.[16]

TO THE EDITOR:

The nature of suspended solids plays a part in causing or preventing foaming and priming in boiler water. If suspended solids act like alumina or glass balls in permitting solutions to boil without bumping, then no foaming or priming occurs.

My experience has shown that, of the materials found in boiler water, calcium in combination with either carbonate or phosphate will prime or carry over with low concentrations. For six years I have been working on a new system, and believe it is now nearly perfected and soon will be more generally released.

Tests were made on a 1044-hp Sterling boiler—200 lb pressure, no superheater, 200 to 300 per cent of rating. This boiler was turbined every 14 weeks, and if the concentrations were great enough, priming and foaming would occur. The method of feedwater treatment was changed so that without the use of any phosphate, the boiler was fed with water having from 3 to 7 grains of hardness, with zero hardness according to the soap test in the boiler. After the first turbining, this boiler was not turbined again for three years, and when it was, the deposits found in the tubes and side walls were negligible, and the drums could be cleaned with a dustpan and broom.

Formerly, the tubine was cleaned yearly. Three years after the feedwater treatment was changed the casing was removed and the deposit on the blades was so small that it was replaced without cleaning.

The same method was tried upon a 165-lb boiler with superheater feeding a turbine. Foaming and carry-over had been present and the turbine had to be cleaned every five months. The use of metaphosphate was discontinued and the new method was tried, with better steam quality for equal and greater concentrations.

The same method, using only orthophosphates in place of soda ash, has been on trial for more than five months in a 600-lb, 700-F, boiler, with no priming or foaming. The boiler tubes are clean.

In tests we have carried the chlorides as high as 50 grains with alkalinity of 200 grains with less than one-quarter per cent of moisture in the steam.

WILLIAM F. PETERS, JR.[17]

TO THE EDITOR:

My experience with controlled treatment of locomotive-boiler feedwaters in wayside tanks with soda ash, resulting in the precipitation of large quantities of carbonate sludge in the boilers, substantiates Professor Foulk's statements[15] to the effect that carbonate sludge in a boiler not only does not aggravate foaming, but conversely, in some cases at least, decreases the foaming tendency of the boiler water.

For several years the Alton Railroad used soda-ash-treated locomotive-boiler feedwater at Bloomington, Ill., varying between 50 and 70 grains hardness, at

[13] Professor of Mechanical Engineering, Lehigh University, Bethlehem, Pa. Mem. A.S.M.E.

[14] Mechanical Engineer, Yarnall-Waring Co., Philadelphia, Pa. Mem. A.S.M.E.

[15] "Suspended Solids in the Foaming and Priming of Boiler Water," by C. W. Foulk, MECHANICAL ENGINEERING, June, 1936, pp. 372–374.

[16] Commercial Testing and Engineering Co., Chicago, Ill. Mem. A.S.M.E.

[17] Water Engineer, Pelham, N. Y.

which time the locomotives using that water could be operated without foaming with boiler-water saline concentrations 100 to 150 grains higher than was possible in contemporary locomotives operating at other terminals using much softer waters. Apparently, sludge did not accentuate foaming; nor can it be assumed that sludge was the only factor decreasing the foaming tendency. But I am convinced that sludge is one important factor, particularly sludge resulting from considerable hardness, a large percentage of which is magnesium hardness.

Recently, a comparatively soft impounded water supply has been substituted for the hard well-water supply at Bloomington, and the boiler-water solids concentration that can be safely maintained without foaming trouble is at least 100 grains lower than was formerly allowable.

My experience has proved to me that a large amount of sludge in the presence of alkalinity equivalent to at least 20 per cent of the total saline content provides boiler water having less foaming tendency than the same water reduced to low hardness (less than 10 grains), because a low-hardness water does not provide sufficient precipitate to form a good sludge, resulting in a more or less finely divided suspension which becomes peptized by organic hydrophilic colloids, or by inorganic hydrophilic colloids like colloidal silica or complexes. This sort of suspension presents a large surface area and when adsorbed in the water surfaces will stabilize foam films. Low alkalinity and particularly low carbonate ion content of boiler water will also cause a nonsludging precipitate which will serve to stabilize foam films.

Further, experience with an accurate foam-indicating device has consistently demonstrated that locomotive boilers using exclusively Zeolite-treated and lime-soda-treated (1 to $1^1/_2$ grains residual hardness) waters foam at lower concentrations (of dissolved solids) than similar waters having larger quantities of sludge-forming hardness, providing that the alkalinity ratio remains the same.

L. O. GUNDERSON.[18]

[18] Vice-President, Dearborn Chemical Co., Chicago, Ill.

THIS MONTH'S AUTHORS

FOR several years a movement has been gathering headway in the engineering societies to establish a group whose function it would be to stimulate interest in the history of engineering in this country by securing authentic records, if possible, from the men who were associated with the events recorded. It is felt that this closer view of the record may result in the preservation of more details and greater accuracy. Within the past month a Joint Division on Engineering History was organized, as reported on page 760 of this issue. This group has agreed to sponsor, as one of its early activities, a session on the history of the steam turbine in the United States, to be held at the 1936 Annual Meeting of The American Society of Mechanical Engineers. The first of the three papers appears as the leading article of this issue.

EMIL E. KELLER and FRANCIS HODGKINSON, who are joint authors of the paper on development of the steam turbine by the Westinghouse Machine Company, were important factors in the events which brought the Parsons steam turbine to this country for manufacture by the Westinghouse Machine Company. Mr. Keller was the representative of Mr. Westinghouse in negotiations with Sir Charles Parsons that resulted in the purchase of rights to manufacture the Parsons type of turbine in the United States. He was, at that time, general manager of the Westinghouse Machine Company, having been brought to Mr. Westinghouse's notice by his work at the Chicago Centennial Exposition, for which Mr. Westinghouse had contracted to provide the illumination. As part of the agreement with Sir Charles Parsons, Mr. Keller secured for Westinghouse the services of Francis Hodgkinson, at that time an engineer engaged in the manufacture of the Parsons steam turbine. Mr. Hodgkinson came to this country in 1896, and since then has been intimately associated with the development of the turbine by the Westinghouse interests. Both Mr. Keller and Mr. Hodgkinson are members of the A.S.M.E.

Power engineers in this country have come to regard with high respect the engineering developments of the Milwaukee Electric Railway and Light Company. Readers of the A.S.M.E. Transactions of several years ago are familiar with the pioneer work in pulverized-fuel firing done by the late John Anderson in Milwaukee power plants. One of Mr. Anderson's successor, F. L. DORNBROOK, member, A.S.M.E., describes in the present issue some of the unique features of design and some of the operating experiences at the Port Washington plant of the Milwaukee Company, a plant that engineers have been talking about for many months and holding the record for heat rate in steam power plants using coal for fuel. Mr. Dornbrook joined the Milwaukee Company in 1902 and was closely identified with the design and construction of the Port Washington Plant. He is at present chief engineer of power plants for the company.

ARTHUR H. SENNER is an associate mechanical engineer with the Bureau of Agricultural Engineering, U. S. Department of Agriculture. He has been identified with tests on domestic oil burners, on which he writes in this issue, carried on by the Bureau in the laboratories of the Johns Hopkins University, from which he was graduated in 1923. He has been connected with the Bureau since 1924.

L. J. ST. CLAIR is manager for the Carboloy Company in the Philadelphia district. Following his graduation in 1923 from the University of Maine he spent three years in the factory-training course of the General Electric Co. Prior to assuming his present position he spent three years in industrial engineering in various plants of the General Electric Company throughout the country.

One of the recent benefits that physics has bestowed upon engineering is the contributions that physicists have made to the quieting of machinery. E. J. ABBOTT, who heads the Physicists Research Bureau in Ann Arbor, is no stranger to MECHANICAL ENGINEERING readers, for articles by him on the subject of noise reduction and the measurement of the quality of surface finishes will be remembered. In his present article Doctor Abbott describes several typical cases of noise reduction and the manner in which the sources of noise were discovered and treated. He will deliver a demonstration lecture on the silencing of machinery at the 1936 Annual Meeting of the A.S.M.E.

RALPH E. FREEMAN, economist, head of the department of economics and social science at the Massachusetts Institute of Technology comments on consumer cooperatives in a book review on this subject.

MAX JAKOB is a name familiar to students of thermodynamics for the past quarter century in connection with investigations in the thermal and physical properties of steam. His recent lecture tour, covering this country from coast to coast, afforded those to whom the name had long been more legendary than real an opportunity of discovering a kindly and able scientist, with a brilliant intellect and a keen but quiet sense of humor, a passion for intellectual honesty, and a reverence for accuracy and research. Returning to Germany, Doctor Jakob left behind him the manuscript copy of his six lectures, of which the three on condensation appear in this issue. Until January 1, 1936, Doctor Jakob was connected with the Physicalisch-Technischer Reichstalt, Berlin, Germany. The work which engaged his lifelong activities as a scientist is going forward under the powerful stimulus that only a great scientific intellect can provide. The list of his scientific writings and accomplishments is too long for record in these abbreviated sketches.

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Group Leadership

Group Leadership. By Robert D. Leigh. Norton & Co., Inc., New York, 1936. Cloth, $5^1/_2 \times 8$ in., 259 pp., $2.50.

Reviewed by John J. Hader[1]

DISCUSSION leaders and chairmen have for some time been aware that voluntary groups and associations are most urgently in need of a set of psychological rules of order to do for the informal group what Robert's "Rules of Order" did for formal group procedures.

This book makes steps in that direction, but unfortunately devotes most of its effort to the problems of the larger formal group for which Robert's "Rules of Order" was written. The arrangement of the subject matter leaves, by implication at least, the idea that the conduct of large formal groups is built on a foundation of small group deliberation. This reviewer feels that it is a mistake to assume that a single procedure can be written to fit both types or that one is merely an extension of the other. There is a real qualitative difference in the methods of the small informal and the larger formal group.

It follows, therefore, as an axiom that the larger a group the more formal must its procedures be and formality is only another name for control or restriction of participation. Therefore, the confinement or limitation of participation is the principal function of the chairman of the formal group. (It is formal by reason of the fact that it is made up of interest groups or elements whose ideas or purposes are already clarified or partially formulated and thus ready for action.)

In the informal group devoted for the most part to "discussion," the function of the chairman is that of encouraging, releasing, guiding, qualifying, augmenting and only occasionally repressing the expression of participants. In the informal group the chairman or leader must be self-effacing and indirect in his techniques and in the formal group he must be self-imposing and direct. It is only rarely that the one person has the qualities to be a successful leader of both types of meetings.

"Group Leadership" is a worth-while contribution to that growing body of knowledge on the more skillful operation of conferences and official groups.

We need still to explore and invent techniques for the leader or chairman of thinking groups, of how to release certain people and inhibit others; how to shift from an argument between two people to a discussion which progresses from point to point and invites the participation of a larger number of the group. Above all, we need to become aware that most of us still all too frequently take part in social deliberation for reasons of personal self-assertion rather than for a genuinely objective sense of the group's need.

[1] Washington, D. C. Joint author, with E. C. Lindeman, of "Dynamic Social Research."

Statistics

Code of Preferred Practice for Graphic Presentation: Time Series Charts. By Sectional Committee on Standards for Graphic Presentation, The American Society of Mechanical Engineers, New York, N. Y., 1936. Paper, 8.5×11 in., 68 pp., $1.

Graphs: How to Make and Use Them. By Herbert Arkin and Raymond R. Colton. Harper and Brothers Publishers, New York, N. Y., 1936. Cloth, 6×9 in., 224 pp., $3.

Elements of Statistics. By Harold T. Davis and W. F. C. Nelson. The Principia Press, Inc., Bloomington, Indiana, 1935. Cloth, $7^1/_4 \times 10$ in., 424 pp., $4.

Reviewed by J. V. Holsinger[2]

THE problem of statistics can be classified under three heads: Problems of (1) specification, (2) estimation, and (3) distribution. First, the specification problem of statistics means the selection of the qualitative nature of the hypothetical universe from which the sample is drawn. If this universe is known a priori, there is no problem of this type; if it is not known, the adequacy of the choice may be tested a posteriori. Second, the problem of estimation is that of knowing how best to calculate from the sample estimates of the parameters of the universe; this is generally devised by the statistician from common-sense consideration of the methods most suitable to the case being studied. Last, when the exact form of the distribution of the calculated statistics, or the probable error of the parameters, is known, the problem of the statistical treatment of the data has been elucidated.

It is toward the elucidation of statistical data that these books under review have been prepared. "Time Series Charts" and "Graphs" relate to one aspect of statistical estimation; they give a simple and clear presentation of the fundamental principles of graphics, first presented by DesCartes in 1637 and Playfair in 1786. These works show how to give (1) a truthful, pictorial representation of the statistical data, (2) a clear, easily read and understood graph, and (3) a well-designed and constructed chart that will attract and hold the attention of the reader. An intensive treatment of time series alone is given in "Time Series Charts." "Graphs" not only covers time-series charts but includes cosmographs, nomographs, map graphs, and control charts, together with the mathematics essential to their choice and construction. The A.S.M.E. book is recommended as being the best for time-series charts. "Graphs" is, in the reviewer's opinion, the only worth-while publication on all types of charts to appear since the American Statistical Association's report of 1915, and is highly recommended to those presenting data in all types of graphical form.

Statistical textbooks generally attempt either to develop in the layman an appreciation and understanding of the rudimentary methods without a real knowledge of mathematics or to develop a practical statistician for industry who has a background of rigid mathematics. The latter type of individual is the engineer; the "Elements of Statistics" also falls into this second class. This book touches all three of the problems of statistics. The treatment emphasizes, in decreasing order of importance, estimation, distribution, and specification. The problems of estimation and distribution are treated together because a statistic without a measure of its error is practically meaningless.

[2] Shattuck Campus, Faribault, Minn.

After a preliminary analysis of statistical data, Davis and Nelson present a discussion of the graphical analysis of data, six kinds of averaging, index numbers and the text of their significance, analysis of time series together with curve fitting, correlation, and problems in sampling and the theory of probability. An unusual feature of this book are the appendixes. A great many statistical tables are given, e.g., the probability and the χ-square functions. The book is excellently suited for the engineer, who has the basic training in mathematics, as an aid in preparing himself to be an able statistical practitioner. The book is further recommended as a textbook for the engineering college.

Books Received in Library

AIRCRAFT ENGINES, Theory, Analysis, Design, and Operation. By A. B. Domonoske and V. C. Finch. John Wiley & Sons, New York, 1936. Cloth, 6 × 10 in., 342 pp., diagrams, charts, tables, $3.75. This book is designed for use by undergraduate and postgraduate students in engineering courses. It also forms a collection of material which is largely new, and which should prove valuable to all who are concerned with aircraft engines. It covers the basic theory and principles of design and operation. The authors have endeavored to obtain a balance treatment of the various phases of the subject and to assemble the material in a serviceable manner.

AIRPLANE DESIGN, PERFORMANCE. By E. P. Warner. Second edition. McGraw-Hill Book Co., New York and London, 1936. Cloth, 6 × 9 in., 653 pp., illus., diagrams, charts, tables, $6. This is the first of two volumes intended to replace the author's "Aerodynamics of Airplane Design," published in 1927. It is devoted to performance and the basic aerodynamic laws and phenomena, and the collected data, which control performance. The work is intended for the student of design and calls only for "a very modest knowledge of mathematics of collegiate grade."

BIBLIOGRAPHY OF PULP AND PAPER MAKING, 1928–1935. Compiled by C. J. West; published for The Technical Association of the Pulp and Paper Industry by Lockwood Trade Journal Co., New York, 1936. Cloth, 6 × 9 in., 803 pp., $8. This book brings together, in a single volume, the substance of the annual bibliographies published under the auspices of the Technical Association of the Paper and Pulp Industry. The material is classified in accordance with a good scheme and an author index is provided. Some fourteen thousand articles are included, and while completeness is not claimed, it is improbable that much of importance has been missed. All those who either make or use paper and pulp will find the book an indispensable key to the literature in this field.

DAVISON'S TEXTILE BLUE BOOK, Handy Edition, Seventy-First Year, July, 1936–July, 1937. Davison Publishing Co., New York, 1936. Cloth, 5 × 8 in., 1274 pp., illus., maps, $5. The current issue of this annual directory again provides a comprehensive, accurate list of those engaged in the textile trade in the United States, Canada, and Mexico. Manufacturers of textiles, dyers, bleachers, converters, brokers, warehouses and compresses, and dealers in all materials are included, with information about equipment, officers, products, etc. The work is the standard directory in its field.

DIE ELEKTRISCHE KRAFTÜBERTRAGUNG, Vol. 3, part 1. Bau und Betrieb des Kraftwerkes. By H. Kyser. Third edition. Julius Springer, Berlin, 1936. Cloth, 6 × 10 in., 573 pp., illus., diagram, charts, tables, 45 rm. This volume of Professor Kyser's important treatise is devoted to the mechanical equipment of electric power plants. The design and operation of steam plants, Diesel and gas engines, and hydraulic plants are discussed in a comprehensive way and from a modern, practical point of view. The book is written from the viewpoint of the designer and operator of electric plants. This edition has been entirely rewritten.

ELEMENTS OF MECHANICS. By H. A. Erikson. Third edition. McGraw-Hill Book Co., New York and London, 1936. Cloth, 6 × 8 in., 269 pp., illus., diagrams, charts, tables, $2.25. A text based on a quarter course at the University of Minnesota. The book makes a special attempt to crystallize out the basic relations underlying Newtonian mechanics and to lead gradually from the simpler concepts to the more complex, through adherence to the sequence of length, time, and mass.

ENGINEERING ALLOYS, Names, Properties, Uses. By N. E. Woldman and A. J. Dornblatt. American Society for Metals, Cleveland, Ohio, 1936. Leather, 6 × 10 in., 622 pp., tables, $10. This handbook tabulates, in convenient form, the trade names, manufacturers, composition, properties, and uses of 8200 engineering alloys. The information is indexed from various points of view, making it possible to obtain any desired information quickly. The book will be of great value to all those who use ferrous and nonferrous alloys.

FIELD ENGINEERING, a Handbook of the Theory and Practice of Railway Surveying, Location, and Construction, vol. 1, text. By W. H. Searles. Twenty-first edition. Revised and enlarged by H. C. Ives. John Wiley & Sons, New York, 1936. Leather, 4 × 7 in., 403 pp., diagrams, charts, tables, leather, $4. The principal changes in the text of this edition are that the chapter on "String-lining curves" is by Prof. Philip Kissam, and that the chapter on "Highway curves" has been entirely rewritten. The tables have been improved and tables of "corrections for subchord lengths" and of the "elevation of the outer rail in inches" are given. These changes add to the usefulness of the standard handbook of railway engineering.

HANDBOOK OF ENGINEERING FUNDAMENTALS. (Wiley Engineering Handbook Series, Vol. 1), edited by O. W. Eshbach. John Wiley & Sons, New York and London, 1936. Leather, 6 × 9 in., 1081 pp., diagrams, charts, tables, $5. This is the first volume in the proposed new "Wiley engineering handbook series." It is intended to be a companion to any other volume of the series, in which will be found those fundamental laws and theories of science which are basic to engineering practice. The volume is essentially a summary of the principles of mathematics, physics, and chemistry, the properties and uses of materials, the mechanics of solids and fluids, and the commonly used mathematical tables. A discussion of contractual relations is included.

HANDBUCH DER DOSENFERTIGUNG. By W. Friebel. V.D.I. Verlag, Berlin, 1936. Paper, 6 × 8 in., 99 pp., illus., diagrams, charts, tables, 10 rm. This book is, we think, the first devoted to the manufacture of tin cans. The author provides a clear, practical account of materials, machinery, and methods, based upon personal experience in the industry. Data are included on both seamed and seamless cans.

HEAVISIDE'S OPERATIONAL CALCULUS, as Applied to Engineering and Physics. (Electrical Texts.) By E. J. Berg. Second edition. McGraw-Hill Book Co., New York and London, 1936. Cloth, 6 × 8 in., 258 pp., diagrams, charts, tables, $3. The new edition of Dr. Berg's exposition of Heaviside's operational calculus contains a number of appendixes in which various numerical problems are worked out in detail and additional information on the theory of his use of the "unit function" is given.

INDUSTRIAL DUST. By P. Drinker and T. Hatch. McGraw-Hill Book Co., New York and London, 1936. Cloth, 6 × 9 in., 316 pp., illus., diagrams, charts, tables, $4. Discusses various phases of the problem of dust control in its relation to the health of workmen, emphasizing the cooperative nature of the problem as one for both engineers and physicians, and presenting principles and methods for designing and operating dust-control equipment. The physical aspects of dust and fume suspensions and their effect upon man; the analysis, measurements, and microscopy of fine dusts; the practical control of dusts and the use of dust respirators are considered.

KRAFTFAHRTECHNISCHE FORSCHUNGSARBEITEN, No. 2. V.D.I. Verlag, Berlin, 1936. Paper, 8 × 12 in., illus., diagrams, charts, tables, 3.50 rm. The first paper in this collection of researches on problems of automotive engineering deals with the displacement of oil when compressed between gear teeth. Certain conclusions of practical use in the lubrication of gears are derived. The second paper considers the distribution of stresses between the contacting surfaces of tire and road, and describes an instrument which is used for measuring these at various points. The final paper discusses the phenomena in the injection systems of high-speed Diesel engines.

MASCHINENFUNDAMENTE und andere dynamische Bauaufgaben. Teil I. By E. Rausch. V.D.I. Verlag, Berlin, 1936. Paper, 6 × 8 in., 111 pp., illus., diagrams, charts, tables, 9 rm. This is said to be the first work to treat comprehensively of foundations for engines and other heavy machinery. This volume, the first of three, is complete in itself and is devoted to the general principles of design and construction for foundations subjected to dynamic stresses. The subject is treated from a practical point of view.

MITTEILUNGEN AUS DEN FORSCHUNGSANSTALTEN, bd. 4, heft 7, July, 1936, pp. 157–186.

V.D.I. Verlag, Berlin. Paper, 8 × 12 in., illus., diagrams, charts, tables, 3.40 rm. The relative merits of different types of joints in butt welds, as regards safety, cost, and shrinkage, are discussed in the first paper in this number. The second paper treats of the design of crane frames. In the third paper, methods of changing the setting time of cement are discussed, and the effects of changes upon the other properties investigated. The final paper calls attention to the advantages to be gained of using tie-rods in welded machine frames.

MITTEILUNGEN der Materialprüfungsanstalt an der Technischen Hochschule Darmstadt, heft 8. STEIGERUNG DER DAUERHALTBARKEIT VON FORMELEMENTEN DURCH KALTVERFORMUNG. By A. Thum and W. Bautz. V.D.I. Verlag, Berlin, 1936. Paper, 6 × 8 in., 891 pp., illus., diagrams, charts, tables, 8.50 rm. This report covers an investigation of the possibility of increasing the fatigue resistance of machine elements by local cold-shaping. The causes of increased resistance and the suitability of various processes were investigated, and the increases were determined by numerous tests. A bibliography is also included.

NATIONAL TRANSPORTATION POLICY. By C. S. Duncan. D. Appleton-Century Co., New York and London, 1936. Cloth, 5 × 8 in., 315 pp., tables, $3. The author of this book, as an economist in the employ of the Association of American Railroads, has for some years studied the problems that have their source in the competitive relationships between different agencies of transportation. He here presents the results of his experience. The relations between the great transportation agencies, railroads, highways, waterways, pipelines, and airways, are discussed, and a policy is outlined for adjusting them to each other and for establishing a proper relationship.

OTTO LILIENTHAL, Der Erste Flieger. By G. Halle. V.D.I. Verlag, Berlin, 1936. Cloth, 6 × 8 in., 192 pp., illus., diagrams, charts, tables, 4.80 rm. This biography of the famous aviator is based upon family recollections and papers, and provides an interesting, comprehensive account of Lilienthal's life and work. As an authoritative account of pioneer efforts, the book will be valued by students of aviation.

PRACTICAL AIR CONDITIONING. By H. L. Alt. Domestic Engineering Co., Chicago, 1936. Cloth, 5 × 8 in., 259 pp., diagrams, charts, tables, $1. A simple, practical handbook on air conditioning which can be understood by the average dealer in heating and ventilating equipment, is provided in this volume. Appropriate methods for conditioning the air in offices, hospital rooms, theaters, shops, department stores, and residences are illustrated by practical examples.

PRINCIPLES OF HEATING, VENTILATING, AND AIR CONDITIONING. By A. M. Greene, Jr. John Wiley & Sons, New York, 1936. Cloth, 6 × 9 in., 446 pp., diagrams, charts, tables, $4.50. This textbook is intended as a college text for upper-class students and also as a handbook for the engineer and architect, for whose convenience it assembles in one volume all the data needed for design. The book offers a logical exposition of the subject, accompanied by authoritative data, which will be welcomed as an up-to-date exposition.

PUBLIC UTILITY INDUSTRIES. By G. L. Wilson, J. M. Herring, and R. B. Eutsler. McGraw-Hill Book Co., New York and London, 1936. Cloth, 6 × 9 in., 412 pp., diagrams, charts, tables, $3.50. This work affords a survey of the economic, legal, and social characteristics of public-utility enterprises, together with a critical study of their organization, management, services, and rate structures. The utilities discussed include the gas industry, the electric light and power industry, the water-supply utility, public automobile transportation, urban street-car, bus, and rapid-transit transportation, interurban electric-railway transportation, pipeline transportation, and telephone, telegraph, cable, and radio communication. The book is intended as an introduction to the broader problems which are common to all utilities, and which will serve as a background for the intelligent discussion of rates, regulation, etc.

QUANTITATIVE ANALYSES. By O. Brunck. Theodor Steinkopff, Dresden and Leipzig, 1936. Cloth, 6 × 10 in., 223 pp., diagrams, charts, 6 × 10 in., 9 rm. The author, a student and the professional successor of the great Freiberg teacher, Clemens Winkler, has prepared this text to perpetuate the methods of analysis which Winkler introduced and which he intended to describe in a text that was never finished. The book gives a careful selection of methods for determining the important elements. The discussion of general manipulations and equipment is unusually detailed and critical.

LA RÉMUNERATION ET LE CONTROLE DU TRAVAIL DANS l'INDUSTRIE. By C. Casacof. Dunod, Paris, 1936. Paper, 7 × 10 in., 99 pp., diagrams, charts, tables, 14 fr. A concise, clear study of wage systems and methods of production control, by a prominent French authority. Various methods are analyzed and conclusions drawn as to their comparative merits.

SCIENCE MUSEUM, South Kensington, CLASSIFICATION FOR WORKS ON PURE AND APPLIED SCIENCE IN THE SCIENCE MUSEUM LIBRARY. Third edition. His Majesty's Stationery Office, London, 1936. Paper, 7 × 11 in., 132 pp., 5 s. (Obtainable from British Library of Information, N. Y., $1.50.) This publication should be of interest to technical libraries and also to individual engineers who wish to arrange personal files, for it provides, in English, an abridgment of the Universal Decimal Classification, which is coming more and more into general use. This abridgment devotes most attention to the subjects of pure and applied science and technology. An extensive index is included.

STEEL PHYSICAL PROPERTIES ATLAS. By C. N. Dawe. American Society for Metals, Cleveland, Ohio, 1936. Cloth, 9 × 11 in., 87 pp., charts, tables, $2.50. This volume presents, in graphic form, the physical properties of S.A.E. steels, cast steels, plates and rounds, and steels of high-tensile strength, as affected by composition and heat treatment. Thirty-five three-color charts are used, covering the steels and steel castings most generally used. The values given are average values and are claimed to be conservative. The method of presentation makes the book easy to consult.

TECHNICAL DRAWING PROBLEMS. (Engineering Science Series.) By F. E. Giesecke, A. Mitchell, and H. C. Spencer. Macmillan Co., New York, 1936. Paper, 9 × 11 in., 93 pp., diagrams, $1.40. This book contains 93 detachable sheets of American standard size, accompanied by the necessary minimum information for solving the problems. The references are to authors' "Technical Drawing," but the problem book can be used with any good reference text.

THEORY OF LUBRICATION. By M. D. Hersey. John Wiley & Sons, New York, 1936. Cloth, 6 × 9 in., 152 pp., diagrams, charts, tables, $2.50. This volume is based upon a series of public lectures on the mechanics of lubrication given at several engineering schools in 1934 and 1935. It aims to give the scientific background of modern lubrication, so that the problems arising in practice may be better understood, and is addressed to physicists and engineers. The treatment is physical, rather than mathematical. Good bibliographies are appended to each chapter.

VERY LOW TEMPERATURES, Their Attainment and Uses, as illustrated in a special exhibition held in the Science Museum, March–May, 1936. By T. C. Crawhall. Board of Education, Science Museum; His Majesty's Stationery Office, London, 1936. Paper, 6 × 10 in., diagrams, charts, tables, 6 d. (British Library of Information, New York, $0.20.) This pamphlet gives a brief sketch of the physical principles underlying the attainment of very low temperatures and of their scientific and industrial applications. Chapters are also included on temperature and pressure measurement, liquefaction and solidification of gases, storage and transport, and the properties of substances at low temperatures.

WERKSTOFF-HANDBUCHES STAHL UND EISEN. Ergänzungsblätter Serie IV. Verlag Stahleisen, Düsseldorf, 1936. Paper, 6 × 8 in., 14 sheets, diagrams, charts, tables, 5.25 rm. The fourth supplement to the "Steel and Iron Handbook" contains 14 new sections and complete revisions of two old sections. New information is provided on fatigue resistance, soldering and brazing, brittleness, high-grade structural steel, heat-resistant steels and cutlery steels, on heat treatment and other topics.

DER WERT DER WARMEERSPARNIS, erläutert an der elektrowirtschaftlichen Gesamtstatistik Deutschlands und der Vereinigten Staaten von Amerika 1912–1934; ein betriebswirtschaftlicher Beitrag zur Kostendynanik. By F. zur Nedden. R. Oldenbourg, Munich and Berlin, 1936. Paper, 7 × 10 in., 163 pp., diagrams, charts, tables, 8 rm. The broad question discussed in this work is: When does the investment of further capital to effect greater savings of fuel become unprofitable? Through an analysis of the statistics of the German and American electric power industries, the author has derived a method for determining this point.

ZWEITAKDIESELMASCKINEN kleinerer und mittlerer Leistung. By J. Zeman. Julius Springer, Vienna, 1935. Cloth and paper, 6 × 9 in., 245 pp., illus., diagrams, charts, tables, 20 rm.; paper, 18 rm. This volume provides a detailed, comprehensive treatise on the design and construction of modern small and medium-sized two-stroke Diesel engines. A large amount of material of value to designer and manufacturer is provided by an engineer with experience in this field. Descriptions and drawings of a number of European designs are included.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Papers, Society Affairs, and Social Events—A.S.M.E. Annual Meeting

New York, November 30–December 4, 1936

SINCE our October announcement (see pages 673–674 of that issue) further details and plans for the Annual Meeting, New York, N. Y., Nov. 30 to Dec. 4, of The American Society of Mechanical Engineers have been made public.

Registration Fee for Nonmembers

A registration fee of two dollars will be charged nonmembers of the A.S.M.E. attending the 1936 Annual Meeting. Members will be granted the privilege of inviting nonmembers to attend the meeting without payment of the fee by writing to the Secretary requesting that his guests be admitted without fee.

Program

In general, annual meetings of the A.S.M.E. cover three groups of member interest. There is, first, the technical phase, for which sessions devoted to the reading and discussion of engineering papers are provided, as well as inspection tours of Metropolitan plants, and meetings of technical committees. Then there is that group of meetings and activities devoted to the affairs of the Society, such as the business meeting, the meetings of Council, the Conference of Local Sections' Delegates, and a host of lesser gatherings of administrative and other committees, formal and informal. And finally, enveloping all, is the social aspect, which is formally recognized in the Annual Dinner and President's Reception, in Honors Night, and informally in many opportunities for the renewal of acquaintanceships and the making of new ones, and for luncheon and dinner gatherings.

To work these three important phases of a meeting of more than 2000 persons is a task in which the Committee on Meetings and Program, the Committee on Professional Divisions, and numerous other committees and officers have been engaged for several months. How well this has been accomplished may be estimated by reading the program printed in this issue.

Technical Program

In last month's announcement attention was directed to the especial efforts expended this year to organize the technical program with fewer simultaneous sessions than have sometimes been offered in the past. A distinction has also been made in the types of papers presented. Three categories of papers have been set up. In the first are technical papers of permanent value that are being presented for the purpose of eliciting extensive and active discussion. Practically every one of these papers has been set in type and published in the Transactions or MECHANICAL ENGINEERING. In the second category are technical papers, few in number, of permanent value, but of a nature difficult to discuss orally. These appear on the program as being presented by title. They will be published later in the Transactions, and discussion of them will be by correspondence. The third group consists of less formal papers and discussions, announced as panel discussions, symposia, or progress reports, in some instances combined with luncheon meetings. These will be reported in MECHANICAL ENGINEERING after the meeting. The informality of the luncheon discussion is rich in possibilities for wider acquaintanceship among members having common interests.

For the first time in many years technical sessions will be presented in the evening. The purpose of these evening sessions is twofold. First, they provide an opportunity for members, particularly younger men in the Metropolitan Section who find it impossible to get away during the day, to attend and take part in the technical features of the meeting. Second, they relieve the daytime program of what would otherwise be conflicting simultaneous sessions.

It will be noted also that this year the technical sessions extend through Friday with a group of papers devoted entirely to aeronautics. These sessions are being conducted jointly with two other engineering societies interested in aeronautics.

The technical program is given in complete form in this issue, and inasmuch as practically all of the papers to be presented for discussion will be preprinted in issues of MECHANICAL ENGINEERING and the Transactions that will be in the mail in advance of the meeting, no attempt will be made at this time to summarize their contents.

At a luncheon on Tuesday noon a feature not announced in our last month's issue will be offered under the auspices of the Committee on Relations With Colleges. Prof. J. R. Connelly, of Lehigh University, has developed a program devoted to engineering education, at which W. H. Carrier, of the Carrier Corporation, and Nevin E. Funk, of the Philadelphia Electric Company, will present the views of industrialists. Prof. Huber O. Croft, of the University of Iowa, will speak for the engineering colleges.

Society Affairs

For many years the Conference of Local Sections' Delegates has been an important feature of A.S.M.E. Annual Meetings. This year the delegates will assemble on Sunday, November 29, to become acquainted with one another and organize for the conduct of such business as they may see fit to consider. The delegates will lunch together at the Engineers' Club on Sunday noon, and will reassemble

About Railroad Fares for the Annual Meeting

There will be no special reduced railroad fares to New York for the Annual Meeting in December. The railroad passenger organizations are not now granting any special convention rates, except to those traveling from one city *in coaches* in groups of 25.

The present reduced regular rates now in force for pullman travel are slightly higher than our convention rates for the last few years.

It is suggested that those members wishing to come in groups to the Meeting, at such distances where coach travel would not make it inconvenient, get in touch with the chairmen of their Local Sections, through whom arrangements may be made.

thereafter. At a buffet supper, at which members of the Council will be present, subjects of major interest will be discussed informally and an opportunity will be provided for the renewal of acquaintanceships.

On Monday the delegates will continue their deliberations, and will take part in the Annual Business Meeting of the Society scheduled for Monday afternoon.

The Council will also meet on Monday. At the business meeting Mr. Batt will deliver his presidential address which, this year, is to be devoted to a discussion of Society problems. The 1936 Council will meet on Friday as usual, at which time it will complete its duties. The 1937 Council, under the administration of James H. Herron, will convene for organization immediately thereafter.

Social Events

Among the social activities, Honors Night, which will be celebrated on Tuesday, will be the first formal gathering of the 1936 Annual Meeting. On this occasion certain medals and awards will be conferred, and James Rowland Angell and Paul Cravath, lawyer, will speak on George Westinghouse.

Wednesday night will be devoted to the Annual Dinner to new members and the Presidents' reception. It will be held at the Hotel Astor as usual. At this time the Hoover Gold Medal will be conferred upon Ambrose Swasey, past-president and honorary member, A.S.M.E. (see page 754 of this issue). The speaker at the dinner, who will be the Thurston Lecturer, will be announced in our December issue. The Presidents' Reception and a dance will follow the dinner.

Harvey N. Davis, president, Stevens Institute of Technology, has assumed personal charge of Honors Night and the Annual Dinner for the Meetings and Program Committee.

Westinghouse Commemoration Exercises

In commemoration of the ninetieth anniversary of the birth of George Westinghouse, former past-president and honorary member of The American Society of Mechanical Engineers, appropriate exercises will be held on Tuesday afternoon, to be followed Tuesday evening, as one of the features of Honors Night, by two addresses. President James Rowland Angell, of Yale University, who has been designated 1936 Towne Lecturer, will speak on a subject appropriate to the occasion based on the work of George Westinghouse, and will be followed by Paul Cravath, who was closely associated with Mr. Westinghouse and who served with him on the famous Board of Patent Control.

The afternoon exercises will present, in a novel manner, some of Mr. Westinghouse's contributions to technology and engineering. Roy V. Wright, past-president A.S.M.E., Chairman of the A.S.M.E. George Westinghouse Memorial Committee, will preside, and Charles F. Scott, professor-emeritus of electrical engineering, Yale University, will lead discussions by a group of former Westinghouse associates.

Other Events

As announced elsewhere, page 754, an exhibition of photographs by engineers will be displayed on the fourth floor of the Engineering Societies Building. A small admission charge will be made.

The usual college reunions and plant visits are being arranged and will be announced in the final program.

A program for women guests is being prepared by the A.S.M.E. Women's Auxiliary under the direction of R. F. Gagg of the Committee on Meetings and Program.

Dinner With Institute of Aeronautical Sciences

As a feature of the sessions on Friday to be held jointly with the Institute of Aeronautical Sciences will be a dinner to be held on Friday evening at the Biltmore Hotel. The Guggenheim Medal will be awarded on this occasion to George W. Lewis, director of aeronautical research, National Advisory Committee for Aeronautics, Washington, D. C.

Hotel Rates

Members desiring information on hotel rates should address the Secretary requesting a list of the principal hotels in New York and the rates charged during the Annual Meeting.

Registration Fee at Annual Meeting

There will be a registration fee of $2.00 for nonmembers attending the 1936 A.S.M.E. Annual Meeting. This is in accordance with the new ruling of the Standing Committee on Meetings and Program.

Members wishing to bring nonmember guests may avoid this fee by writing to the Secretary of the Society before November 20 asking for a guest-attendance card for the Annual Meeting. This card, upon presentation by a guest, will be accepted in lieu of the registration fee.

Tentative Program

MONDAY, NOVEMBER 30

9:30 a.m. Council Meeting

2:00 p.m. Business Meeting

Presidental Address

8:00 p.m. Power Session

Domestic Oil Burners, by A. H. Senner[1]

Steamotive—A Complete Generating Unit, Its Development and Test, by E. G. Bailey, A. R. S. Smith, and P. S. Dickey*

8:00 p.m. Management Session

Time and Motion Study—Research and Application

An Investigation in Some Hand Motions, by Ralph W. Barnes*

Introduction of a Time and Motion-Study Program, by W. R. Coley*

Motion Study as a Basis of Establishing Proper Employee Training and Personnel Relations, by A. Williams, Jr.*

Social Aspects of Motion Study, by Allan H. Mogensen*

TUESDAY, DECEMBER 1

9:30 a.m. Strength of Materials

The Creep Curve and Stability of Steels at Constant Stress and Temperature, by S. H. Weaver[1]

The Interpretation of Creep Tests for Machine Design, by C. R. Soderberg[1]

Discussion of Research Activities and Progress Report to Sponsors, by Special Research Committee on Effect of Temperature on Metals

9:30 a.m. Coal-Cleaning Symposium

Coal Washing and the Baum Jig, by G. L. Arms[1]

Coal Preparation by the Air-Sand Process, by T. Fraser[1]

The Rheolaveur Coal-Cleaning Process, by J. Griffen[1]

9:30 a.m. Heat Transfer

Problems in the Collection and Evaluation of Data for Design of Steam-Generating Units, by B. J. Cross*

The Thermal Conductivity of Liquids, by J. F. Downie Smith[1]

Temperature and Combustion Rates in Fuel Beds, by M. A. Mayers (to be presented by title)*

Discussion of Heat-Transfer Activities

9:30 a.m. Sugar

Bone-Char Filtration, by W. A. Bemis*

A New Angle on Sugar Crystallization, by A. L. Webre*

12:30 p.m. Luncheon

Sugar Group: Round-Table Discussion of What Is New in Sugar-Plant Engineering

12:30 p.m. Luncheon

Discussion: Activities of Petroleum Division

12:30 p.m. Luncheon

Lubrication Research and Application

2:00 p.m. Safety and Hygiene in Industry

Practical Results from Safety Contests, by Harold Miner*

Engineer's Part in Industrial Hygiene, by Wm. Yant*

Engineering Value of Adequate Operating Instructions, by Dan Royer*

2:00 p.m. Cinder Catchers

Fuels Panel Discussion

Discussers: W. G. Christy, H. F. Johnstone,

[1] Published in A.S.M.E. Transactions for November, 1936.

* Not preprinted.

C. W. d'Hedberg, Ollison Craig, H. F., Hagen, L. C. Whiton, Jr., Paul Thompson, J. J. Grob, H. P. Hardie, C. S. Messler, M. D. Engle, J. H. Leitch, H. B. Reynolds, Stanley Brown

2:00 p.m. Fluid Flow and Aerodynamics

The Effect of Installation on the Coefficients of Venturi Meters, by W. S. Pardoe[1]
Extended Information on Orifice Coefficients, by S. R. Beitler*
Square-Edge Inlet and Discharge Orifices for Measuring Air Volumes in the Testing of Fans and Blowers, by L. S. Marks[1]
The Modified I.S.A. Orifice With Free Discharge, by M. P. O'Brien and R. G. Folsom*

2:00 p.m. Railroads

The Use of Alloy Steels for Side Frames and Bolsters of Freight-Car Trucks, by D. S. Barrows[1]
Report on Railroad Aerodynamics Subcommittee of Aeronautic Division (to be presented by title)
Progress Report of Railroad Mechanical Engineering.

4:30 p.m. Westinghouse Ninetieth Anniversary Commemoration

The Engineering Achievements of George Westinghouse—a discussion by his former associates

8:00 p.m. Honors Night

Towne Lecture, by Dr. James Rowland Angell, President of Yale University

WEDNESDAY, DECEMBER 2

9:30 a.m. Oil and Gas Power

Supercharging of Internal-Combustion Engines with Blowers Driven by Exhaust-Gas Turbines, by A. Buchi, Winterthur, Switzerland*
Diesel-Engine Operating, Maintenance, and Outage Data, by Lee Schneitter*
Discussion of Oil-Engine Cost-Data Report

9:30 a.m. Cutting Metals

A Study of Cutting Fluids Applied to the Turning of Monel Metal, by O. W. Boston and W. W. Gilbert[1]
Comparative Torque and Horsepower Requirements of Standard Four-Flute and Spiral-Flute Taps, by H. L. Daasch[1]
Cemented Carbide Tool Maintenance and Application, by L. J. St. Clair[2]

9:30 a.m. Drying Session

Latest Foreign Developments in Continuous Processing of Stable Fibers, by F. K. Howell
A Theory of Paper Drying, by E. Cowan and B. Cowan[1]
Discussion on Application to Textile Drying, led by M. A. Golrick
Presentation of the Recommended Practice for Testing Drying Equipment

9:30 a.m. Power

Undercooling in Steam Nozzles, by J. T. Rettaliata[1]
Tests of a Large Surface Condenser at Widely Varying Temperatures, Velocities of Inlet Water, and Loads, by G. H. Van Hengel[1]

12:30 p.m. Luncheon

Distribution: Discussion of Product and Sales Research, by Dr. L. Chalkley and W. M. Bristol. Auspices of Management Division.

12:30 p.m. Luncheon

Textiles: Discussion of Developments in Sanforizing, by C. H. Ramsey

2:00 p.m. Power and Applied Mechanics

Superposed Turbine-Regulation Problems, by A. F. Schwendner and A. A. Luoma[1]
Turbine Supervisory Instruments and Records, by J. L. Roberts and C. D. Greentree[1]
Supervising Instruments for 165,000-Kw Turbine at Richmond Station, by H. Steen-Johnsen[1]

2:00 p.m. Machinery and Springs

Discussions of Spring Problems to Include Rubber Springs, Helical Springs, and Spring Materials
Bearing Oil-Ring Performance, by R. Baudry and L. M. Tichvinsky*
Quieting Machinery, by E. J. Abbott[2]

2:00 p.m. Plant Layout Management

(Jointly with Society for Advancement of Management)

Economics of Manufacturing Layout in a Varied Product Plant, to Include Influence of Type of Layout, Function of Feeder Sections, Flexibility, Salvage Value, and the Function of Time Studies, by A. F. Murray*
Time Studies and Their Relation With Factory Layout, by B. C. Koch*

2:00 p.m. Hydraulics

The Cooperative Hydraulic Machinery Laboratory at the California Institute of Technology, by R. T. Knapp[1]
Experimental Determinations of the Flow Characteristics in the Volutes of Centrifugal Pumps, by R. C. Binder and R. T. Knapp[1]

6:30 p.m.

Annual Dinner, Astor Hotel
Thurston Lecture

THURSDAY, DECEMBER 3

9:30 a.m. Management

(Jointly with Society for Advancement of Management and Personnel Research Federation)

Dealing with Workers Today
Modern Principles and Practice of Manufacturing Organizations in Employee-Employer Relationship, by W. G. Marshall, T. I. Phillips, J. H. Priest, and R. M. Rumbel—representatives of the Westinghouse Electric and Manufacturing Company

9:30 a.m. Thermodynamics

(Jointly with A.S.R.E.)

Review of Existing Psychrometric Data With Relation to Practical Engineering Problems, by W. H. Carrier and C. O. Mackey*
Method of Computing Thermal Properties of Oxygen and Nitrogen, and Derivation of a New Equation of State therefore, by W. L. DeBaufre and T. A. Filipi (to be presenced by title)*
Leakage of Gases Through Narrow Channels, by A. Egli (to be presented by title)*

9:30 a.m. Power

Physical-Property Uniformity in Valve-Body Steel Castings, by A. E. White, C. L. Clark, and S. Crocker[1]
Unique Design Features and Operating Experiences at the Port Washington Power Plant, by F. L. Dornbrook[2]

9:30 a.m. Corrosion-Resistant Metals Symposium—I

Introduction to Corrosion-Resistant Metals, by F. H. Speller[3]
Aluminum and Its Alloys, by E. H. Dix, Jr., and R. B. Mears[3]
Construction and Use of Lead Equipment, by G. O. Hiers[3]

12:30 p.m. Luncheon

Maintenance: Discussion of Organization and Management of Maintenance, J. A. Jacobs, Chairman
Discussers: W. C. Zinck, J. I. Thompson, A. Vaksdal, W. O. Larson, A. E. Windle

12:30 p.m. Luncheon

Engineering Education—Topics:
Engineering Education—A Study of Principles Vs. a Curriculum in Memorizing Facts and Theories, by W. H. Carrier*
Applying the Methods of Science and Engineering to Engineering Education, by N. W. Funk*
Encouraging Research in Engineering Education, by H. O. Croft*

12:30 p.m. Luncheon

Discussion of Fluid Mechanics as a Basic Mechanical Engineering Science

2:00 p.m. Corrosion-Resistant Metals Symposium—II

Zinc in the Chemical Industries, by E. A. Anderson[3]
Cast Iron, by Dr. H. L. Maxwell[3]
Copper and Copper-Base Alloys, by R. A. Wilkins[3]

2:00 p.m. Management

Training People to Be Skilled Workers
Symposium sponsored by Management Division, Committee on Education and Training, Society for Advancement of Management and Personnel Research Federation
F. E. Searle, Supt., Ford Motor Car Company's schools, will discuss the selection of apprentices and their training to operate machines
Chas. G. Simpson, Philadelphia Gas Works, will discuss adult education

2:00 p.m. Boiler Feedwater

Discussion of Boiler-Feedwater Problems to

[2] Published in this issue.

[3] To be published in MECHANICAL ENGINEERING for December, 1936.

include Progress Report on Embrittlement and Dissolved Oxygen Determination
Reactions of Sodium Sulphite Under Boiler Operating Conditions, by Prof. F. G. Straub[4]

Corrosion-Resistant Metals
8:00 p.m. Symposium—III

Corrosion-Resistant Steel, by J. H. Critchett[3]
Nickel and Nickel-Base Alloys, by F. L. LaQue[3]

8:00 p.m. Turbine History

The Steam Turbine in the United States
I—Development by the Westinghouse Machine Company, by E. E. Keller and F. Hodgkinson[3]
II—Early Development by the Allis-Chalmers Manufacturing Co., by A. G. Christie[4]
III—A Brief History of Steam-Turbine Development by the General Electric Co., by E. L. Robinson[4]

FRIDAY, DECEMBER 4

Aviation Meeting

(Sponsored jointly by Institute of Aeronautical Sciences, Society of Automotive Engineers, and the A.S.M.E.)

1:00 p.m.

Films will be shown of Aeronautic Research Laboratories

2:00 p.m.

Representatives of European countries to discuss aviation progress

3:00 p.m.

Aviation Five Years Hence
Round-Table Discussion by leaders in the field

6:30 p.m. Dinner Biltmore Hotel

Presentation of Guggenheim Aeronautic Medal to George W. Lewis, Director, Research, National Advisory Committee for Aeronautics

Ambrose Swasey Awarded Hoover Gold Medal

Presentation at Annual Dinner

AT THE Annual Dinner of The American Society of Mechanical Engineers, to be held at the Hotel Astor, New York, on Wednesday evening, December 2, Ambrose Swasey, past-president and honorary member of the Society, and founder of the Engineering Foundation, will have the high distinction of becoming the second recipient of the Hoover Gold Medal.

The Hoover Gold Medal was instituted to commemorate the civic and humanitarian achievements of Herbert Hoover and the first award was made to him in Washington on the occasion of the Fiftieth Anniversary of the A.S.M.E. in April, 1930. Inscribed on the medal is the legend "Awarded by Engineers to a Fellow Engineer for Distinguished Public Service."

The trust fund creating the award is the gift of Conrad N. Lauer, of Philadelphia, past-president of the A.S.M.E. It is held by the A.S.M.E. and is administered by a Board of Award consisting of representatives of the American Society of Civil Engineers, the Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the American Institute of Electrical Engineers.

The personnel of the Board which selected Mr. Swasey as the recipient is as follows: For the A.S.C.E., Ralph Budd, Albert S. Crane, and Thaddeus Merriman; for the A.I.M.E. Scott Turner, Clinton H. Crane, and J. V. W. Reynders; for the A.S.M.E., S. F. Voorhees, C. N. Lauer, and W. H. Kenerson; and for the A.I.E.E., F. B. Jewett, Gano Dunn, and H. H. Barnes, Jr.

A.S.M.E. Awards Announced

To Be Presented at Annual Meeting

THE A.S.M.E. Board of Honors and Awards and its Medals Committee have announced the following list of honors to be conferred at the 1936 Annual Meeting of the Society:

The Holley Medal to Henry Ford of the Ford Motor Company, Detroit, Mich.

The A.S.M.E. Medal to Edward Bausch of the Bausch & Lomb Optical Co., Rochester, N. Y.

The Worcester Reed Warner Medal to Charles M. Allen, professor of mechanical engineering at Worcester Polytechnic Institute, Worcester, Mass.

The Melville Medal to H. A. S. Howarth, Kingsbury Machine Works, Philadelphia, Pa.

The Junior Award to Harwood F. Mullikin, Jr., of Babcock & Wilcox Co., New York, N. Y.

The Undergraduate Student Award to Leon B. Stinson, of Oklahoma Agricultural and Mechanical College.

The Postgraduate Student Award to DeWitt D. Barlow, Jr., of Princeton University.

Members of the Board of Honors and Awards are Herman Diederichs, Chairman, R. C. H. Heck, L. P. Alford, Harte Cooke, and Willis H. Carrier.

The Committee on Medals, functioning under this Board, has as its personnel Kenneth H. Condit, E. O. Eastwood, James H. Herron, Arthur M. Greene, Jr., James W. Parker, Roy V. Wright, L. W. Wallace, John Lyle Harrington, Dougald C. Jackson, Robert Sibley, Carl L. Bausch, R. H. Fernald, Frank M. Gunby, Henry C. Meyer, Jr., and Edwards R. Fish.

A.S.M.E. Calendar

of Coming Meetings

November 30–December 4
Annual Meeting,
New York, N. Y.

May 14–15, 1937
National Rayon Textile Conference, Washington, D. C.

May 17–21, 1937
Semi-Annual Meeting,
Detroit, Mich.

Exhibit of Photography for Engineers 1936 A.S.M.E. Annual Meeting

THE Photographic Group of the A.S.M.E. Metropolitan Section will sponsor the first of two annual exhibits of pictorial photography for engineers at the Annual Meeting of the Society in December in New York. An invitation is extended to the entire Society membership to submit prints. The 1937 exhibit may be national in scope. The editor of MECHANICAL ENGINEERING will be entitled to free use of any print for the cover or inside pages, with proper acknowledgment.

The following instructions will assure a measure of uniformity and safe return:

(1) The Group will try to hang at least one print from each contributor. Space limitations may prevent hanging more than four from any one contributor. Mounts should be light-colored, simple cards, either 15 × 20 in. or 16 × 20 in. The use of rubber cement is suggested. Place title of picture and name of maker in pencil on the front of the mount beneath the print. The name and return address of the maker should appear on the back of the mount.

(2) The prints should be securely wrapped and protected with corrugated strawboard. To avoid payment of first-class postage, all letters should be sent separately or attached to the outside wrapping. Inclose remittance for fifty cents to cover return handling, postage, and insurance. Prints may be called for in person. While the Group will exercise all reasonable care in the handling and return of prints, liability will be limited to parcel-post insurance if returned by mail.

Address all prints: John F. Guinan, Annual Photographic Exhibit, A.S.M.E., 29 West 39th Street, New York, N. Y.

To insure the best display, prints should be received by November 23, 1936. The Annual Meeting occurs the week beginning November 30, 1936.

Engineers From Abroad Join With A.S.M.E. at Niagara Falls Meeting

Papers on Power a Feature

AUGMENTED by many engineers from overseas who had been in Washington attending the Third World Power Conference and were passing through Niagara Falls on post-conference study tours, members of The American Society of Mechanical Engineers met at the Hotel Niagara on September 16–19. The registration totaled 320.

En route to Niagara Falls many members availed themselves of stopping off at Schenectady to join with the engineers taking the study tours in a visit to the works of the General Electric Company.

Meetings of Executive Committee and Senior Councilors

The Executive Committee of the A.S.M.E. Council met at the Niagara Falls Hotel on Wednesday, September 16, and the important actions that engaged their attention are reported on page 757 of this issue, A.S.M.E. News section.

Following the meeting of the Executive Committee President Batt called together a Conference of Senior Councilors. There were present at the conference, of the Senior Councilors, Harry R. Westcott, William A. Shoudy, James W. Parker, R. L. Sackett, James H. Herron, Alex D. Bailey, John A. Hunter; and of advisory members of the Council, K. H. Condit (Professional Divisions) and J. N. Landis (Local Sections). Others present were W. D. Ennis, treasurer, C. E. Davies, secretary, and Ernest Hartford, assistant secretary.

The senior councilors, as they are called, were appointed by President Batt as a result of action of the Council at its meeting of October 11 and 12, 1935, mention of which was made in our issues of December, 1935, page 808, and March, 1936, page 198.

Each councilor presented a résumé of his experiences during the previous eight months with the Local Sections, Student Branches, and individuals in his area.

There was general agreement that the intimate contact which had been developed by each senior councilor with problems of the sections and branches in his district had been of great value not only to the councilor by giving him an insight into Society problems but also to the local groups with which contact had been made and to the Society itself.

In general there was agreement that this function of the senior councilor should not interfere in any way with the existing organizations concerned with member contact, such as the Local Sections Committee and Delegates' Conference.

It was agreed that the councilors should meet with the local groups of delegates in their meetings in various areas, but that the councilors as a group should not meet with the Group Delegates' Conference during the Annual Meeting.

The Secretary presented tabulations of meeting programs held in Groups 1, 4, and 5, which were reviewed briefly and led to the conclusion that the councilors may render valuable service by making suggestions regarding the technical program work of the sections. From the brief review of this summary it was obvious that many program-making agencies of the sections would be glad to have aid in improving the quality of the technical programs. The councilors also agreed that it was desirable to devote time at the coming section conferences to the question of improving section meetings.

Considerable discussion was devoted to the responsibilities of the senior councilors, and to the suggestion that some of the correspondence between members of the Society and its officers might be referred to the senior councilors with the result that they would then be in a position to represent the members more effectively in discussions of the Council.

Technical Sessions

Interest in the papers on steam and water power ran high, and good attendance and lively discussion made the sessions at which these papers were presented very much worth while. Contributions to the discussion by engineers from other countries added greatly to the value and interest of the sessions. A program of the technical sessions appeared in our September issue, page 604.

Inasmuch as the papers delivered at the power session were published in advance of the meeting in our issue for September, 1936, no attempt will be made to summarize them. They concerned trends in present practice. It is hoped that the complete discussion that was presented in writing will be published as soon as space permits.

Highlights of Dr. Otto Schoene's Paper

Dr. O. Schoene's paper on German steam-engineering practice, which was not received in form for publication, brought out some interesting facts. The comparatively large number of installations for pressures in excess of 1500 lb per sq in. and the more recent installation of several boilers with pressures in excess of 1800 lb per sq in. indicated quite a different trend from that in the United States. A few plants will even operate at pressures more than 2000 lb per sq in. and a temperature in excess of 900 F. The advantage claimed is a considerably reduced boiler surface, for which a less expensive economizer surface is substituted.

Of the special boilers, about which much has been written in the technical literature, the La Mont boiler seems to enjoy the greatest favor, although on the whole the special boiler designs are not being as much considered as they used to be.

The reduction of the number of drums in high-pressure boilers to two in number and even one also marks an interesting feature of development.

The problem created by feedwater conditioning in plants operating with a large percentage of make-up has been successfully met with the steam converter, a heat exchanger in which low-pressure steam is generated with the exhaust from the high-pressure stage. The experience with carry-over apparently parallels that in this country as the discussion following the reading of the paper indicated.

As to steam-turbine practice, the reduction in the number of turbine casings and the use of higher speeds also showed some similarity in development here and abroad. A new type of radial steam turbine by Siemens Schuckert was mentioned. An interesting feature about it is the elimination of the high-pressure packing by introducing an overhanging wheel.

The scarcity of underfeed-stoker firing aroused considerable interest and discussion brought out interesting facts about German fuels and about the development of the Kraemer type of pulverizer which is integral with the boiler, a method of firing unknown in this country. Its ability to fire low-volatile coals with high ash content indicated possibilities with certain hard-to-burn fuels in this country. The question of double firing as necessitated by reason of economy was also discussed.

Hydraulic Sessions

At the sessions devoted to water power and hydraulics, hydraulic laboratories and trends in hydroelectric developments in the United States and Canada were discussed. These papers were published in the October issue of the A.S.M.E. Transactions.

The two hydraulic sessions were well attended and interesting. At the morning session, devoted to laboratory work in hydraulics, the discussion added some information to that contained in Mr. Hooper's paper. It was also announced that the annual meeting would include a paper describing in considerable detail one of the laboratories mentioned by Mr. Hooper—that at the California Institute of Technology. The discussion on Lieutenant Falkner's paper gave some particularly interesting information on the practice of using different grain sizes and densities in studying scour in model tests. It was pointed out that for similar action in model and prototype, the grain size and the density of the material are both a function of scale ratio.

The afternoon session was devoted to papers on hydroelectic practice. Both papers dealt with progress in the improvement of power-plant practice. The increasing use of outdoor generating equipment and adjustable-blade (Kaplan) turbines was pointed out. Discussion was quite lively on the relative merits of fixed-blade and movable-blade propeller turbines. It appeared to be the consensus of opinion that in locations where the water supply was more than sufficient for the power demand, there was no point in the use of the

Kaplan turbine, but where efficiency at part loads was important the Kaplan turbine possessed definite advantages. Both sessions were fortunate in having in attendance foreign engineers, members of the World Power Conference, who were able to supplement the discussion with information about the practice abroad.

Drying

The session on drying was held on Friday morning with a paper on drum and contact drying by Guy Harcourt. The discussion which followed dealt with several interesting drying problems for which special solutions had to be worked out. The subject of combined contact drying followed by air drying as a means of improving the quality of the product was extensively discussed. Questions were asked on the operation of contact driers, especially as they pertain to the dairy industry. A. Weisselberg led a discussion on drying developments and showed a film on this subject. This stimulated general comment on the activities of the Drying Committee of the Process Industries Division which had sponsored the session and the need for more papers giving information on the performance of process equipment.

Wood-Industries Session

The Wood Industries Division held two sessions Friday morning and evening, and participated in a woodworking-plant inspection trip in the afternoon. In the morning session the discussion on elimination of plant waste was led by Thomas D. Perry. Mr. Perry reviewed previous work done in woodworking plants in reduction of waste and improvements that could often be made which would, of course, vary with the type of product manufactured. Mr. Thompson presented a paper on grinding and maintenance of cemented carbide fitted saws and woodworking knives, and particularly emphasized the application of these tools to wood cutting. This paper will be published later in Transactions.

In the evening session R. P. A. Johnson of the Forest Products Laboratory presented an unusual review on the substitution of woods. He showed some of the government's curves on recent changes in the use of woods for certain types of products. He discussed in an amusing vein requirements for wood that some trades demanded, mentioning in particular those for coffins and lead pencils. With the latter, the question of taste of the wood was mentioned as an example of trade requirements that were not necessary and often contradictory. The second paper, by R. J. Moore on "Use of Synthetic Resins in Modern Varnishes for Wood Protection," was published in our October issue. Considerable discussion on Mr. Moore's paper, particularly in regard to requirements and methods used for painting equipment subject to corrosion and located in buildings that had to stand weathering, resulted.

Mr. Moore stated that for general bridge-construction work, including projects such as canal gates and locks, suitable U. S. Engineers' Specifications were available. For example, Anti-corrosive Primer Specification 10-03(3) would procure a primer of good resistance to water and alkalies and would contain rust-inhibiting pigments. This should be followed by two coats of Specification 10-04, Aluminum Paint. Both of these specifications call for coatings based on so-called 33-gal straight phenolic-resin vehicle. Mr. Bescher discussed the problem of the sealing of creosoted wood poles. He was referred to the new two-minute air-drying sealing coats containing aluminum powder based on the XK-3962 type of resin. Another problem discussed was with regard to the protection of steel to withstand steam and dilute zinc-chloride solution. For this type of problem Mr. Moore suggested the use of a short oil, anticorrosive primer, followed by a chemically resistant varnish containing aluminum. Such a varnish would be the $12^1/_2$-gal length specially resistant type, the specifications for which were given in Table 4 of the paper.

On Thursday morning there was a transportation session with a paper on "Performance of Diesel-Electric Locomotives" and "The Mechanics of the Car Retarder," and on Thursday afternoon a session on aircraft power-plant accessories and bearing design.

Plant-Inspection Trips

Engineers in attendance at the meeting were given an opportunity to visit many of the power plants and industrial establishments in the vicinity of the Falls and Buffalo. For those interested in power the Schoelkoepf hydroelectric station of the Niagara Falls Power Company, so rich with historic associations for the engineer, was a major attraction. Steam power was admirably represented at the Huntley Station, well known for its pioneer application of the slag-tap furnace.

Popular among the industrial visits were those to the Curtiss Aeroplane and Motor Corporation, Buffalo, and to the new Lackawanna strip-mill plant of the Bethlehem Steel Company. Other plants which afforded the members of the A.S.M.E. the courtesy of inspection were the Kittinger Company, the Larkin Company, the Niagara Wall Paper Company, the Shredded Wheat Bakeries, the Buffalo Foundry and Machine Company, and the Colonel Ward Pumping Station of the Buffalo Water Works System.

500 at Dinner Meeting

On Thursday evening 500 members and guests sat down for dinner at the Niagara Hotel under the joint auspices of the World Power Conference, the Engineering Institute of Canada, and the A.S.M.E. Following the dinner Norman R. Gibson, member, A.S.M.E., vice-president and chief engineer, Niagara Falls Power Company, delivered a brief address of welcome. He said that the international character of the audience was most appropriate at Niagara Falls where hydroelectric power was undertaken following an extensive study of the possibilities of developing the Falls by the International Niagara Commission. It was his opinion that, in spite of great progress in hydroelectric practice since the report of the International Commission, much research remains to be done, and it would be unfortunate if the price of electricity should fall so low that it could not continue.

As toastmaster, W. L. Batt, president, The American Society of Mechanical Engineers, extended greetings, saying that while international boundaries might separate geographical areas they could not separate friends. There were no boundary lines between engineers, he said, and hence, of all professions, engineering was best qualified to carry the torch of truth into a world in which there is too much of the darkness of untruth. Among the benefits which would surely follow the Third World Power Conference, not the least, in his opinion, would be the better understanding of American engineers on the part of their guests from abroad.

Wouter Cool, general secretary of the Royal Institution of Engineers, the Netherlands, oldest engineering society in the world, spoke briefly and paid tribute to the work of the late Calvin W. Rice among engineers abroad.

Dr. Henrich Schult, president, Verein deutscher Ingenieure, was introduced by President Batt; and Conrad Matschoss, director, V.D.I., spoke for him, first in German and then in English. He recalled the long period of friendly relations between the V.D.I. and the A.S.M.E., and of the value in international understanding, of the German Speaking Circle in Great Britain and the English Speaking Circle in Germany.

As representative of the Engineering Institute of Canada, John Murphy presented some amazing statistics relating to his country, and extended an invitation to all engineers to participate in the semicentennial in June, 1937, of the E.I.C.

The principal speaker was Dr. William F. Durand, past-president and honorary member, A.S.M.E., and president, the World Power Conference Committee. He reviewed some of the high points of the principal addresses at Washington, the impressive starting, by President Roosevelt, of the turbines at Boulder Dam, and the solar engine constructed by Dr. C. G. Abbot of the Smithsonian Institution.

It had been planned that Doctor Durand would confer honorary membership in the A.S.M.E. on Alex Dow on this occasion, but circumstances held Mr. Dow in Detroit, and hence this pleasantly anticipated feature of the dinner had to be omitted.

Following Doctor Durand's address, John C. Parker, of the Brooklyn Edison Company, who was joining the transcontinental tour of the World Power Conference, expressed the appreciation of the Conference to the A.S.M.E. for the privilege of taking part in the meeting at Niagara Falls.

Committees for the Meeting

The committee of the A.S.M.E. Buffalo Section in charge of arrangements for the Niagara Falls Meeting was under the chairmanship of James L. Yates, and consisted of C. E. Harrington, C. Gale Kiplinger, W. A. Miller, P. Dubosclard, H. D. Munson, and J. A. Fish.

Norman F. Gibson served as chairman and Thomas H. Hogg as vice-chairman of the Third World Power Conference Buffalo-Niagara Falls Committee.

A.S.M.E. Executive Committee Meets at Niagara Falls

On September 16, 1936, the Executive Committee of the Council of The American Society of Mechanical Engineers met at the Hotel Niagara, Niagara Falls, N. Y., prior to the technical sessions of the Niagara Falls Meeting. President William L. Batt presided, and there were present, of the Committee, Harry R. Westcott, William A. Shoudy, and James W. Parker; of the Senior Councilors, R. L. Sackett, E. W. O'Brien, James H. Herron, Alex D. Bailey, and John A. Hunter; of the advisory members, K. H. Condit (professional divisions), and J. N. Landis (local sections); also W. D. Ennis, treasurer, C. E. Davies, secretary, and Ernest Hartford, assistant secretary.

Actions of general interest are summarized as follows:

Representatives Appointed

Henry A. Lardner was appointed A.S.M.E. representative on the United Engineering Trustees to serve the unexpired term of H. V. Coes.

William L. Batt was appointed A.S.M.E. representative on the John Fritz Medal Board of Award.

Membership Status

Among recommendations of the Board of Review that were approved was one of general interest. The present policy of readmitting resigned members by payment of only prorated dues will be continued, and former members who were dropped will be readmitted on payment of $10 plus prorated dues to September 30, 1937.

Employment Service

It was voted that an additional amount of $1250 be made available for the Engineering Societies Employment Service and that the Finance Committee be requested to study the budget for 1936–1937 and recommend the changes necessary to provide this amount, it being understood that the total of $4250 may not all be needed if income of the New York office increases and expenses reduce substantially.

Publication Changes Approved

Approval was given to a proposal to broaden the scope and interest in the news section of Mechanical Engineering (A.S.M.E. News, see issue of October, 1936, pp. 613–614) and to incorporate with it the former *Student Branch Bulletin*.

Research Committee

A Research Committee agreement was approved as follows:

Approval was voted of the revised patent agreement signed by W. C. Schroeder covering developments in the work at the Nonmetallic Minerals Experiment Station of the Bureau of Mines, New Brunswick, N. J., for the Subcommittee on Alkalinity and Sulphate Relations in Boiler Water Salines.

Power Show Policy

It was voted to adopt the policy that no officer of the Society shall participate in his official capacity as an adviser for the Power Show or similar exhibit.

Relations With Other Societies

At the request of the Engineers' Club of Tulsa, Okla., an exchange of courtesies was approved.

V. M. Palmer, C. F. Scott, and C. E. Davies were appointed A.S.M.E. representatives to attend the annual convention, Knoxville, Tenn., October 19 to 21, of the National Council of State Boards of Engineering Examiners.

Codes and Standards Approved

The following codes and standards were approved: A.P.I.-A.S.M.E. Rules for Design, Construction, Inspection and Repair of Unfired Pressure Vessels for Petroleum Liquids and Gases (first revised edition), standards for circular and dovetail forming-tool blanks, and standards for pipe plugs of cast iron, cast steel, or forged steel for use with fittings included in American Standards for 125-lb and 250-lb cast-iron screwed fittings and 150-lb malleable-iron screwed fittings.

Appointments

The following appointments were reported:

Library Committee, A. R. Mumford (four-year term).

Power Test Codes Committee No. 2 on Definitions and Values, R. J. S. Pigott, Chairman, Lyman J. Briggs, Ward F. Davidson, S. Logan Kerr, A. L. Kimball, Lionel S. Marks, Frank G. Philo, Julian C. Smallwood, Philip W. Swain, Albert C. Wood.

Special Research Committee on Lubrication, A. L. Beall, R. E. Wilkin.

Boiler Code Subcommittee on Ferrous Materials, P. E. McKinney, W. G. Humpton, L. A. Sheldon, E. C. Wright.

Tellers of Election, D. L. Holbrook, George W. Kelsey, R. B. Purdy.

Committee on National Defense, H. I. Cone, Chairman, H. E. Coffin, W. C. Dickerman, Thos. A. Morgan, J. L. Walsh.

"Mechanical Catalog," Wm. T. Conlon, Robert E. Thayer.

Bureau of Welding Research (formerly American Bureau of Welding), James Partington.

United Engineering Trustees, D. Robert Yarnall (reappointed, three-year term).

Engineering Foundation, W. E. Fulweiler (reappointed four-year term).

Engineering Foundation, Research Procedure Committee, W. E. Fulweiler (one-year term).

Engineers' Council for Professional Development, C. F. Hirshfeld (reappointed three-year term).

Washington Award Commission of Western Society of Engineers, C. B. Nolte (reappointed two-year term).

United Engineering Trustees Fund Raising Committee, George Felker.

Inauguration of G. C. Dillman as President, Michigan College of Mining and Technology, August 6, James H. Walker.

Inauguration of Dr. Friley as President, Iowa State College, October 7, Thomas L. Wilkinson.

Plans for A.S.M.E. Semi-Annual Meeting, Detroit, May, 1937, Under Way

Tentative plans for the 1937 Semi-Annual Meeting of The American Society of Mechanical Engineers, to be held in Detroit, Mich., with May 17–21 as the tentative date, have been announced by James W. Parker who is in charge of arrangements for the meeting.

The Detroit Section, acting as host for the meeting, has appointed a special technical program committee which has been actively engaged in developing a planned technical program. The committee consists of H. T. Woolson, Chairman, W. A. Carter, C. L. Eksergian, Sabin Crocker, J. A. Clauss and James W. Parker.

The opening day, it is planned, is to be given over to an all-day meeting of the A.S.M.E. Council, and to inspection tours in the afternoon.

On the following three days technical sessions will be held morning and evening, and the afternoons will be devoted to plant visits and group sessions of the Professional Divisions.

For the six technical sessions the following topics are being considered: (1) Contribution of Automotive Engineering to Other Fields, (2) Light-Weight, High-Speed Trains, (3) Steel and Its Applications, (4) Management and Mass-Production Methods, (5) Improved Methods of Fabrication, and (6) Summary of Week's Program and Its Implications.

The list of speakers who are being invited to prepare papers and take part in the discussions is a particularly notable one. Further details will be reported in Mechanical Engineering as they develop.

Papers for presentation at this meeting in either of the group division sessions must be submitted by February 1. Members wishing to have papers considered for the meeting

should immediately send a 300-word outline of the paper either to Sabin Crocker, secretary of the Detroit Committee, or to the attention of the Standing Committee on Professional Divisions, A.S.M.E., 29 West 39th Street, New York, N. Y.

October Meeting of Power Test Codes Committee

THE meeting of the A.S.M.E. Power Test Codes Committee, Dr. R. H. Fernald, chairman, held on October 5, was well-attended and a number of the items on its order of business are of general interest to the members of the Society.

Early in the meeting it was announced that Committee No. 2 on Definitions and Values had been reorganized since the April meeting and that its new personnel is as follows: Messrs. R. J. S. Pigott, chairman; L. J. Briggs, W. F. Davidson, S. L. Kerr, A. L. Kimball, L. S. Marks, F. G. Philo, J. C. Smallwood, P. W. Swain, and A. C. Wood.

The secretary reported also that W. W. Johnson had been added to Committee No. 19 on Instruments and Apparatus, C. F. Hirshfeld, chairman.

From the Process Industries Division the committee received a suggestion that a new A.S.M.E. code be developed for large steam-generating units employing the heat balance as the basis. After a brief discussion the committee voted to request Committee No. 4 on Stationary Steam-Generating Units, Edwards R. Fish, chairman, to give consideration to the desirability of formulating such a code.

Among the several committees that reported progress was the committee which is preparing a test code on fans. Chairman M. C. Stuart stated that copies of a tentative draft of this code are now in the hands of the committee members and others known to be particularly interested in this subject. The principal sections of this code are (*a*) the definitions of heads; (*b*) the method of measuring total head by survey with impact tube; (*c*) the method of obtaining static head by total head minus velocity head; (*d*) the method of measuring quantity by combination of orifice and pitot tube; (*e*) the use of straighteners; (*f*) the description of four basic-test arrangements, and the permitting of a choice as to which test arrangement to use, consistent with the fan type; and (*g*) the new pitot tube. This committee held a meeting on the afternoon of the same day. It is understood that a few copies of its code are still available for distribution.

Committee No. 19, C. F. Hirshfeld, chairman, reported the approval and publication in pamphlet form of the following five sections of Instruments and Apparatus: Part 3, Temperature Measurement—Chapter 2 on Radiation Pyrometers; Part 10 on Flue and Exhaust Gas Analyses; Part 14 on Linear Measurements; and Part 20 on Smoke-Density Determinations.

This means that 27 of a total of 35 sections originally planned have been completed.

Professional Practice

SCRUPULOUS conformity to the recognized rules by which engineers have agreed to conduct their professional practice and their relations with their clients and employers, will entitle them to the respect and honorable regard of their associates and the public. Violation of these rules, willful, involuntary, or because of ignorance, is likely seriously to injure if not entirely to destroy a professional reputation and career. In accordance with its desire and duty to enhance the dignity of the engineering profession and the public's high regard for the professional conduct of engineers, the Society has reduced to a simple code the essential elements of long-established practice. The engineer who violates this code is subject to disciplinary action by the Society's Committee on Professional Conduct. Practicing engineers and students should be thoroughly familiar with the Code of Ethics which is part of the By-Laws of the A.S.M.E.

A Code of Ethics for Engineers

That the dignity of his chosen profession may be maintained, it is the duty of every engineer

(1) To carry on his professional work in a spirit of fairness to employees and contractors, fidelity to clients and employers, and devotion to high ideals of personal honor.

(2) To refrain from associating himself with, or allowing the use of his name by, any enterprise of questionable character.

(3) To treat as confidential his knowledge of the business affairs or technical processes of clients or employers when their interests require secrecy.

(4) To inform a client or employer of any business connections, interests, or affiliations which might influence his judgment or impair the disinterested quality of his services.

(5) To accept financial or other compensation for a particular service from one source only, except with the full knowledge and consent of all interested parties.

(6) To advertise only in a dignified manner, to refrain from using any improper or questionable methods of soliciting professional work, and to decline to pay or to accept commissions for work secured by such improper or questionable methods.

(7) To refrain from using unfair means to win professional advancement and to avoid unfairly injuring another engineer's chances to secure and hold employment.

(8) To cooperate in building up the Engineering Profession by the interchange of general information and experience with his fellow engineers and with students of engineering and also by contributions to the work of engineering societies, schools of applied science, and the technical press.

(9) To interest himself in the public welfare and to be ready to apply his special knowledge, skill, and training in the public behalf for the use and benefit of mankind.

Approved by the A.S.M.E. Council, December 5, 1932

Metropolitan Junior Group Plans an Active Year

THE Junior Group of the Metropolitan Section of The American Society of Mechanical Engineers has commenced its activities for the coming year with its Executive Committee assisted by a newly organized Administrative Committee, which is made up of officers of the executive body and the chairman of the junior standing committees and the Study Groups.

Under the guidance of a Program Committee a schedule of two major meetings per month has been arranged and is well under way. The high quality of the meetings already held and those announced for the coming months has attracted enthusiastic audiences. For November a representative of the Crucible Steel Company has been secured to talk on alloy steels, and one from the New Departure Company to discuss applications of ball bearings in the automotive industry.

The Junior Group of the Metropolitan Section is composed of an executive committee, five standing committees on program, membership, nominations, publicity, and the *Student Branch Bulletin*, and study groups devoted to aeronautics, national defense, and the engineer's economic advancement. In addition there is a special survey committee on the consumer-goods industries and an employment advisory committee.

The Committee on the *Student Branch Bulletin*, which carried on the task of editing that publication during the past year, will continue to supply material for the student-branch section of the A.S.M.E. News, recently combined with MECHANICAL ENGINEERING.

A Junior dinner for representatives of the A.S.M.E. student branches in the Metropolitan area has been scheduled by the Membership Committee. Honorary chairmen and officers of the student branches have been invited for the purpose of forming a committee to acquaint student members with the Society and the work of the Junior Group.

The study groups afford Junior members who have special interests opportunities to follow them more closely and profitably, to hear and present papers on subjects related to these interests, and to become acquainted with other young engineers having similar tastes in professional and engineering developments. The popularity of these study groups was demonstrated by the increasing attendance noted at last year's sessions, and has encouraged their sponsors to look upon them as one of the most promising activities of the Junior Group.

The purpose of the Junior Group, in addition to the forming of professional contacts, is to provide worth-while programs for the development of young engineers in the Metropolitan Section as a means of bridging the critical years which lie between graduation from the engineering college and maturity in engineering practice.

W. G. HAUSWIRTH.[1]

[1] Chairman, Junior Group, A.S.M.E. Metropolitan Section.

A.S.M.E. Technical Committee Meetings

THE usual group of October meetings of technical committees sponsored by the Society was held this year during the week of October 26–30.

One of the most important of these meetings was that of the Sectional Committee on Minimum Requirements for Plumbing and Standardization of Plumbing Equipment (A-40), W. C. Groeniger, chairman. At this meeting the committee heard and discussed the reports of its eleven subcommittees and their various subgroups, and conducted other business which had accumulated since its last meeting held in April. The development of plans for the future activity of Subcommittee No. 1 and its related research committee occupied a major portion of the Committee's attention. The first of these will prepare an American Standard Code for the minimum requirements of plumbing and the second will initiate and conduct a broad research program in the plumbing field.

Two new subcommittees of Sectional Committee A-40 held their organization meetings. These are Subcommittee No. 10 on Threaded Cast-Iron Pipe and Fittings for both drainage and pressure purposes and Subcommittee No. 11 on Soldered Fittings for Tubing.

On Friday, October 30, meetings of two subcommittees of the Sectional Committee on Standardization of Pipe Flanges and Fittings (B-16) were held. Subcommittee No. 2 on Screwed Fittings, F. H. Morehead, chairman, met in the morning to review a proposed revision of the American Standard for Malleable Iron Screwed Fittings originally published in 1927. Various details concerned with this proposed revision have been the subject of correspondence among the committee members during the past few months.

Subcommittee No. 3 on Steel Flanges and Flanged Fittings, C. P. Bliss, chairman, met in the afternoon to discuss the proposed revision of the American Standard for Steel Flanged Fittings and Companion Flanges published by the A.S.M.E. in 1932. This committee proposes to bring this important standard in line with the latest practices of industry and to add considerable new material to the present standard, including a new range of sizes for the higher temperatures.

The newly organized Sectional Committee on Standardization of Graphical Symbols and Abbreviations for Use on Drawings (Z-32), H. W. Samson, temporary chairman, held a meeting during the week following meetings of its Subcommittees Nos. 1 and 2. Subcommittee No. 1 on Mechanical Symbols, T. E. French, chairman, took up the development of plans for the future work of its two subgroups and received the report on symbols for pneumatic-tube installations prepared by E. E. Ashley. At its meeting Subcommittee No. 2 on Electrical Symbols discussed the report on the existing conflicts in the electrical group prepared by H. W. Samson, temporary chairman.

Mechanical Catalog Issued by the A.S.M.E.

THE twenty-sixth annual Mechanical Catalog, 1936–1937 edition, was published on October 1 by The American Society of Mechanical Engineers. This issue shows an improvement over the preceding one, both in number of pages of product descriptions carried and in make-up. A new feature is introduced this year—an index that groups the products described by classes, in addition to the usual specific-product index.

The Catalog has three sections: (1) "Catalogs of Industrial Equipment, Materials, and Supplies," arranged alphabetically by names of companies, contains illustrated descriptions of the products manufactured by the companies represented in the book. (2) "Classified Index to Manufacturers" contains the names of over 800 firms, and lists, under 4800 classifications, thousands of items used by industry. (3) "Manufacturers List," an alphabetical list of firms included in this issue, gives addresses and products manufactured.

A.S.M.E. Membership List Address Cards Sent Out

Watch for Them!

A CARD requesting information for a new A.S.M.E. Membership List has recently been sent out to all members of the Society. The Membership List is to be published in February, 1937, as a section of Transactions. The personnel of the Council and all Society Committee and other general information will be included.

All members except those residing outside the United States and Canada (who are given until November 30, since an earlier return would not be possible from distant points) are asked to return the cards not later than November 16.

Every member who is not positive that his listing is already correct should return the card. Change in position, name of the company, or address, either business or mail, should be reported to the Society at this time. The card should be completely and clearly filled out, and particular care should be taken in giving the correct names of companies.

The card asks that members indicate whether mail is to be sent to the home or firm address. Unless otherwise requested, mail will be sent to the firm address. It is also requested that members state under what city heading their names should appear in the geographical section of the Membership List. In general, members are grouped according to their business locations, but it frequently happens that a member gives a business address widely separated from his home address. In such cases it is difficult to know under which city he would prefer to be listed. Members are particularly urged, therefore, not to overlook this question on the card.

As we go to press cards are being received with no names. *Please include your name!*

H. I. Cone, Alex Dow, and Geo A. Orrok Elected Honorary Members of A.S.M.E.

AT THE September 16 meeting of the Executive Committee of The American Society of Mechanical Engineers, William A. Shoudy and C. E. Davies, appointed tellers by President Batt, reported the election to honorary membership in the Society of Rear-Admiral Hutchison I. Cone, U. S. Navy, Retired; Alex Dow, past-president, A.S.M.E., and president, Detroit Edison Company; and Geo. A. Orrok, consulting engineer, New York, N. Y.

It had been planned to confer honorary membership on Mr. Dow on the occasion of the dinner at the Niagara Falls Meeting of the Society, Sept. 18, 1936, but unexpected circumstances prevented Mr. Dow's attendance at that time.

In view of the fact that the 1937 Semi-Annual Meeting of the Society is to be held at Detroit in May, 1937, it is planned to make that meeting the occasion for honoring Mr. Dow.

Conrad Matschoss and Adolph Nägel Honored

ON October 7 about 20 members of the A.S.M.E. and guests met at luncheon in the Engineers' Club, New York, to honor Dr. Conrad Matschoss, director, Verein deutscher Ingenieur, and Dr. Adolph Nägel, professor at the Dresden Technical High School, Germany, who have been traveling in the United States following the Third World Power Conference.

Dr. D. S. Jacobus, past-president, A.S.M.E., presided.

Following the luncheon both of the honored guests spoke briefly. Dr. Matschoss gave some of his impressions of the trans-continental tour from which he had just returned. He recalled the long services of the late Calvin W. Rice for international good will among engineers, and suggested that the tour, in which so many engineers of foreign countries had taken part, would prove valuable in providing better understanding of national and international problems. Dr. Nägel, an authority on Diesel engines, spoke in complimentary terms of the high quality of research work in Diesel engineering he had witnessed during his tour of plants in this country.

Division on Engineering History Organizes

READERS of MECHANICAL ENGINEERING will recall the proposal (see issue of January, 1935, page 63) made following the 1934 Annual Meeting of The American Society of Mechanical Engineers for the formation of a group of members of the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the American Institute of Chemical Engineers who are interested in the history of engineering.

On September 30, representatives of these societies met at the Engineers' Club, New York, and formally organized the Joint Division on Engineering History. There were present, J. K. Finch and R. S. Kirby (A.S.C.E.), Geo. A. Orrok and J. W. Roe (A.S.M.E.), S. D. Kirkpatrick (A.I.Ch.E.), C. E. Davies, secretary, A.S.M.E., and George A. Stetson, editor, A.S.M.E. T. T. Read (A.I.M.E.), who is traveling in China, could not be present.

It was announced that all of the societies named had approved the statement of purpose of the Joint Division on Engineering History prepared by an informal group of society representatives at a meeting held last spring.

Geo A. Orrok was chosen chairman and H. W. Craver, librarian, Engineering Societies Library, secretary of the Joint Division of Engineering History.

Informal discussion of plans for the future followed. It was suggested that sections of the Societies represented on the Joint Division be encouraged to devote meetings to historical subjects, and that a letter be sent to deans of engineering schools informing them of the formation of the Joint Division and asking for names of persons interested in its activities.

Approval was voted of participation of the Joint Division in sponsorship of a session on the history of the steam turbine to be held at the 1936 A.S.M.E. Annual Meeting (see program on pp. 754 of this issue).

National Rayon Technical Conference

THE Textile Division of The American Society of Mechanical Engineers is developing its plans for a National Rayon Technical Conference to be held in Washington, D. C., May 14 and 15, 1937. The Division has asked the following organizations to join it as co-sponsors: American Association of Textile Chemists and Colorists, Committee D 13 of the A.S.T.M., and the United States Institute for Textile Research.

Two committee meetings of representatives of these groups have been held and the Bureau of Standards has appointed a representative on the meeting committee.

The meeting, which will consist of four technical sessions and an evening dinner, will commemorate 25 years of the manufacture of rayon in this country. Those who have aided in the plans for developing the conference are C. H. Ramsey, chairman of the Textile Division, M. A. Golrick, P. A. Johnson, H. Smith, E. Freedman, F. Bonnet, L. A. Olney, B. L. Hathorne, Winn Chase, R. D. Hope, H. Konheim, and W. D. Appel.

President W. L. Batt Visits Western Sections and Student Branches

PRESIDENT W. L. Batt left Philadelphia on September 20, for an extended trip to the Pacific Coast for the purpose of visiting A.S.M.E. Local Sections and Student Branches. He returned on October 16, having visited the following sections: Mid-Continent, Kansas City, Colorado, Utah, Los Angeles, San Francisco, Oregon, Western Washington, Inland-Empire, Nebraska, Tri-Cities, and Milwaukee; and student branches at the University of Kansas, Colorado State College, Colorado School of Mines, University of Southern California, California Institute of Technology, Santa Clara University, Oregon State College, Washington State College, University of Idaho, Iowa State College, University of Iowa, and Marquette University.

Mr. Batt was present at the meeting of Local Sections representatives of Group 7, held at Seattle, Washington, October 3 and 4.

A.S.M.E. Officers Elected for Coming Year

TELLERS of Election R. B. Purdy, D. L. Holbrook, and Geo. W. Kelsey have submitted their report of the ballot vote for directors of The American Society of Mechanical Engineers for 1937, as follows:

Office	Nominee	Votes
President	James H. Herron	2975
Vice-Presidents	James A. Hall	2983
	R. J. S. Pigott	2981
	James M. Todd	2981
Managers	Edward W. Burbank	2983
	Kenneth H. Condit	2981
	Samuel W. Dudley	2982

The total number of ballots cast was 3160, with 2987 valid, and 173 defective.

Biographical sketches of the nominees for office may be found on pages 527–529 of the August, 1936, issue of MECHANICAL ENGINEERING.

Three Research Committees Pass the Hat

STARTING in March, 1936, three of the A.S.M.E. Research Committees have gone back to industry for additional funds to advance their work.

The Joint A.S.T.M.-A.S.M.E. Research Committee on the Effect of Temperature on the Properties of Metals, H. J. French, chairman, began its solicitation in March under the leadership of R. A. Bull. So far the checks received from 29 firms have totaled \$12,300 which is 82 per cent of the amount sought for the current three-year period.

In 1935 the committee began a vigorous attack on the problem of extrapolating results from the customary 1000-hour creep tests to years of service life. Both ferritic and austen-

itic steels are being studied. The following additional subjects are now under investigation: (a) Perfection of High-Temperature Testing Methods (with hope of safely shortening time requirements for test procedures); (b) Seizure of Metals Working in Contact at High Temperature; (c) Effect of Corrosion of 18:8 Steel as the Result of Use at High Temperature; (d) Influence of Subatmospheric Temperatures on Performance Properties of Metals; and (e) Methods of Evaluating Servicability of Metals Subjected to Low Temperature.

In May the A.S.M.E. Committee on Fluid Meters, R. J. S. Pigott, chairman, announced its plan to undertake a four years' study of the coefficients of the long-radius flow nozzle which it estimated would involve the expenditure of a total of $20,000. To date, within a period of five months, 25 firms have subscribed and paid a total of $7500. Chairman E. C. M. Stahl of the committee's finance committee is still actively at work and expects to complete the task within the next few months.

A part of the committee's experimental program will be carried on at the National Bureau of Standards, Washington, D. C. H. S. Bean is directing this work and has assigned the several nozzles to the various laboratories for calibration.

Industry has again subscribed generously to the research on boiler feedwater studies. This is a joint enterprise sponsored by the E.E.I., A.B.M.A., A.W.W.A., A.R.E.A., and the A.S.M.E. This time the committee has been soliciting funds for its Subcommittee No. 6 on Alkalinity and Sulphate Relations in Boiler Water Salines, J. H. Walker, chairman. The response to this call has been the most general of all three. Seventy-two firms and organizations have subscribed amounts varying from $25 to $200. The total amount received to date from these subscriptions is $9265.

This sum will cover the subcommittee's activities for the coming two years and will permit it to continue its experimental studies of the cause and prevention of embrittlement.

Secretary C. E. Davies Visits Sections and Branches in Southeast

At the time of going to press, C. E. Davies, Secretary, The American Society of Mechanical Engineers, was starting on a three-weeks' trip through the Southeastern states for the purpose of visiting A.S.M.E. Local Sections and Student Branches, and attending the Annual Meeting, Knoxville, Tenn., Oct. 19–21, of the National Council of State Boards of Engineering Examiners. Mr. Davies' itinerary included the following local sections: Raleigh, Charlotte, Atlanta, Knoxville, Chattanooga, Birmingham, Louisville, Cincinnati, and West Virginia. It also included the Group 4 Conference of Local Sections at Savannah, Ga., October 16 and 17. Student branches visited en route were Duke University, University of North Carolina, Clemson College, Georgia Tech, and the University of Louisville.

William T. Conlon Elected Vice-Chairman A.S.M.E. Finance Committee

At a meeting of the Finance Committee of the Society on September 15, William T. Conlon was elected vice-chairman of the committee because of the illness of the chairman, Professor Rautenstrauch.

With the Student Branches

Student Branch Doings

Iowa State Branch newly elected officers are Donald G. Schaefer, Maynard L. Adams and Everett W. Waters. . . . .Colorado State Branch officers for 1936–1937 are Harold Stanley, Roy Vorhees, and William Crenshaw.

* * *

Florida Section in conjunction with the Florida Branch will hold a special meeting at the University of Florida, Gainesville, Florida, on October 31, which is school homecoming day. The morning will be devoted to an interesting technical meeting and the afternoon to the football game between Florida and Maryland. Everybody is invited.

* * *

Nevada Branch is planning a trip to Stanford University. Fifteen or more men are expected to take part. This branch has the novel idea of having their members present talks at the meetings based on articles in Mechanical Engineering. In a social way, great plans are being made for the annual Engineers Day and the Engineers Brawl, their annual dance. It is requested that members attending the dance check their six-shooters at the door.

* * *

Rice Branch is putting the burden of preparing an interesting program up to its members by having them fill out a questionnaire. In this way, the officers will be greatly aided in determining the type of speakers and industries the majority of the members are interested in hearing and visiting.

* * *

Nebraska Branch reports that their September 23 meeting was adjourned to the foundry for refreshments. . . . .Chairman H. D. Emmert of the Georgia Tech Branch believes in having the members take an active part in the affairs of the branch by putting them on committees. So far there are committees to take care of programs, publicity, membership, and inspection trips. . . . .Kansas Branch had a turnout of eighty-five students and professors to their annual smoker held on September 24. A fine piano duet was rendered by Bill Ayres and Karl Johnson.

Leslie F. Zsuffa.[1]

The Next Step for Students Is Junior Membership

On page 759 of the A.S.M.E. News Section of this issue will be found a brief résumé of the work of the junior group of the Metropolitan Section, a typical active organization of junior members. This description is of special interest to student members since the natural course for the student member on graduation is transfer to the junior grade and affiliation with the junior group in the area. Even a casual perusal of this picture of the activities of a typical junior group will demonstrate the worthwhileness of such affiliation.

L. N. Rowley, Jr.[2]

A.S.M.E. Annual Meeting Student Program

An outstanding feature of the 1936 Annual Meeting, from the student viewpoint, will be the student luncheon to be held on Wednesday, December 2. This meeting, at which E. W. Burbank, Chairman, A.S.M.E. Committee on Relations With Colleges, will preside, will also be attended by senior and junior members of the Society.

Prominent on the luncheon program will be brief talks by President W. L. Batt and President-elect J. H. Herron. The winners of the Charles T. Main Award and the Undergraduate and Postgraduate Awards will be presented.

All the varied events on the week's program (for details see pages 752–754 of this issue) are open to student members, and inspection trips of special interest will be scheduled on Wednesday, for the convenience of student members attending the luncheon.

New Air-Conditioning Apparatus at Illinois

With the opening of the University of Illinois September 22, one of the most complete pieces of air-conditioning apparatus in this country, installed during the summer months, was made available for the instruction of engineering students.

The working model is large enough to air-condition a lecture room with a capacity for 100 students. It will be suitable for both summer and winter air conditioning. In addition to its availability for instruction of both graduate and undergraduate students, the apparatus may be used for research.

[1] Member Editorial Board for Student Branch News. Jun. A.S.M.E.

[2] Chairman, Editorial Board for Student Branch News. Jun. A.S.M.E.

Members of the College of Engineering staff who designed and selected the apparatus, according to Prof. O. A. Leutwiler, head of the mechanical engineering department, are Prof. J. A. Polson, in charge of the mechanical engineering laboratory; Prof. W. H. Severns, in charge of courses in air conditioning; Prof. H. J. Macintire, authority on refrigeration; A. P. Kratz, research professor of mechanical engineering, and M. K. Fahnestock, research assistant professor of mechanical engineering.

To facilitate the study of the operation of the equipment, inspection doors fitted with glass are located at convenient intervals in the unit, enabling the students to observe what is happening within it.

Other Engineering Activities

Engineering Curricula Accredited by Engineers' Council

FORMAL action in accrediting engineering curricula in 35 educational institutions in New England and Middle Atlantic states by the Engineers' Council for Professional Development has been announced by H. H. Henline, secretary of the Council.

The engineering curricula accredited by the Engineers' Council for Professional Development are only those offered in educational institutions in the New England and Middle Atlantic states, as the Committee on Engineering Schools which acts for the Council in making the investigations and reports on which the accrediting is based, has so far confined its work to these two areas. Hence the lists of accredited curricula should be considered in the nature of a progress report which will be supplemented when the Council has had an opportunity to extend its investigations to institutions in other parts of the country.

Curricula in schools in the United States, not included in the New England and Middle Atlantic areas, will be investigated during the coming year by the Committee on Engineering Schools, and a complete list of accredited curricula will be issued when approved by the Council.

Some institutions and some curricula in the New England and Middle Atlantic states may be added to the list as soon as certain criteria essential for judging them have been determined by the Council.

Basis for Accrediting

In drawing up its list of accredited engineering curricula, the entire Council considered every curriculum separately and based its decision on the reports made by a number of groups of engineers and educators who visited the institutions under the direction of the Council's Committee on Engineering Schools, of which Karl T. Compton, president, Massachusetts Institute of Technology, is chairman. Inspection visits were made by one of these groups to 90 per cent of the educational institutions in the areas mentioned offering engineering curricula leading to degrees, and were made only at the request of the institution formally applying for accrediting by the Council.

The basis for accrediting by the Engineers' Council may be summarized as follows:

Only undergraduate curricula leading to degrees were considered at this time.

Curricula, not institutions, were to be accredited and both qualitative and quantitative criteria were set up as a basis for final action.

Qualitative criteria were evaluated through the inspection committee and included the following:

(1) Qualifications, experience, intellectual interests, attainments, and professional productivity of members of the faculty
(2) Standards and quality of instruction
  (*a*) In the engineering departments
  (*b*) In the scientific and other cooperating departments in which engineering students receive instruction
(3) Scholastic work of students
(4) Records of graduates both in graduate study and in practice
(5) Attitude and policy of administration toward its engineering division and toward teaching, research, and scholarly production.

Quantitative criteria were evaluated through the following data secured from catalogs and other publications and from questionnaires:

(1) Auspices, control, and organization of the institution and of the engineering division
(2) Curricula offered and degrees conferred
(3) Age of the institution and of the individual curriculum
(4) Basis of and requirements for admission of students
(5) Number of students enrolled
  (*a*) In the engineering college or division as a whole
  (*b*) In the individual curriculum
(6) Graduation requirements
(7) Teaching staff and teaching loads
(8) Physical facilities: The educational plant devoted to engineering education
(9) Finances: investments, expenditures, sources of income.

List of Accredited Curricula

The E.C.P.D. has prepared two lists of the undergraduate engineering curricula accredited by it, one arranged by institutions and the other by curricula. Both lists will be published shortly by the E.C.P.D. The list of curricula arranged by institutions follows:

BROWN UNIVERSITY: Civil, Electrical, Mechanical.
CARNEGIE INSTITUTE OF TECHNOLOGY: Chemical (*c*), Civil (*a*), Electrical (*a*), Management (*a*), Mechanical (*a*), Metallurgical (*a*).
CLARKSON COLLEGE OF TECHNOLOGY: Civil, Electrical, Mechanical.
COLLEGE OF THE CITY OF NEW YORK: Civil (*a*), Electrical (*a*).
COLUMBIA UNIVERSITY: Chemical (*b*), Civil (*b*), Electrical (*b*), Industrial (*b*), Mechanical (*b*), Metallurgical (*b*), Mining (*b*).
COOPER UNION INSTITUTE OF TECHNOLOGY: Civil (*c*), Electrical (*c*), Mechanical (*c*).
CORNELL UNIVERSITY: Administrative, Chemical, Civil, Electrical, Mechanical.
DARTMOUTH COLLEGE: Civil.
UNIVERSITY OF DELAWARE: Civil, Electrical, Mechanical.
DREXEL INSTITUTE: Chemical (*d*), Civil (*d*), Electrical (*d*), Mechanical (*d*).
JOHNS HOPKINS UNIVERSITY: Civil, Electrical, Mechanical.
LAFAYETTE COLLEGE: Civil, Electrical, Mechanical (technical option), Metallurgical, Mining.
UNIVERSITY OF MAINE: Civil, Electrical, General, Mechanical.
MASSACHUSETTS INSTITUTE OF TECHNOLOGY: Aeronautical, Architectural, Bus. and Eng. Administration, Chemical, Civil, Electrical, Electrochemical, General, Mechanical, Metallurgy, Mining, Naval Arch. and Marine, Sanitary.
UNIVERSITY OF NEW HAMPSHIRE: Civil, Electrical, Mechanical.
NEW YORK UNIVERSITY: Aeronautical (*c*), Chemical, Civil (*c*), Electrical (*c*), Mechanical (*c*).
NEWARK COLLEGE OF ENGINEERING: Civil, Electrical, Mechanical.
NORWICH UNIVERSITY: Civil, Electrical.
PENNSYLVANIA STATE COLLEGE: Architectural, Chemical, Civil, Electrical, Electrochemical, Industrial, Mechanical, Sanitary.
UNIVERSITY OF PITTSBURGH: Chemical, Civil, Electrical, Industrial, Mechanical, Metallurgical, Mining, Petroleum.
POLYTECHNIC INSTITUTE OF BROOKLYN: Chemical (*c*), Civil (*a*), Electrical (*a*), Mechanical (*a*).
PRINCETON UNIVERSITY: Chemical, Civil, Electrical, Mechanical.
RENSSELAER POLYTECHNIC INSTITUTE: Chemical, Civil, Electrical, Mechanical.
RHODE ISLAND STATE COLLEGE: Civil, Electrical, Mechanical.
UNIVERSITY OF ROCHESTER: Mechanical.
RUTGERS UNIVERSITY: Civil, Electrical, Mechanical, Sanitary.
STEVENS INSTITUTE OF TECHNOLOGY: General
SWARTHMORE COLLEGE: Civil, Electrical, Mechanical.
SYRACUSE UNIVERSITY: Civil, Electrical, Mechanical.
TUFTS COLLEGE ENGINEERING SCHOOL: Civil, Electrical, Mechanical.
UNION COLLEGE: Civil, Electrical.
UNIVERSITY OF VERMONT: Civil, Electrical, Mechanical.
WEBB INSTITUTE OF NAVAL ARCHITECTURE: Naval Architecture and Marine Engineering.

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Worcester Polytechnic Institute: Civil, Electrical, Mechanical.
Yale University: Chemical, Civil, Electrical, Mechanical, Metallurgical.

Notes

(*a*) Accrediting applies to both the day and evening curricula.

(*b*) Accrediting applies to the four-year and five-year curricula leading to the Bachelor of Science Degree.

(*c*) Accrediting applies to day curriculum only. Action on evening curriculum in which the quantitative requirements differ materially from the usual day curriculum has been deferred pending further study by a special subcommittee of the E.C.P.D. Committee on Engineering Schools.

(*d*) Accrediting applies to the five-year cooperative curricula leading to degrees.

(*e*) E.C.P.D. has not received from its subcommittee on Chemical Engineering any recommendations with respect to evening curricula in chemical engineering.

(*f*) Institutions offering several curricula in engineering and for which E.C.P.D. has received recommendations only in respect to Chemical Engineering have not been included in this preliminary list.

Engineers' Council Reelects Scott

Charles F. Scott, member A.S.M.E. and professor-emeritus of electrical engineering at Yale University, was reelected chairman of the Engineers' Council for Professional Development at the fourth Annual Meeting of the Council held in New York on October 6. At the morning session, in addition to the election of officers and chairmen of committees, reports of the Council's committee were presented. Interest centered around the report of the Committee on Engineering Schools, and at afternoon and evening sessions formal action on the accrediting of engineering curricula of educational institutions in New England and Middle Atlantic states was taken. A report on the accredited curricula appears elsewhere in the A.S.M.E. News.

H. H. Henline, national secretary, American Institute of Electrical Engineers, was elected secretary of the Council. By action of the Council the By-Laws were amended to provide for the offices of vice-chairman and assistant secretary, and R. I. Rees, member A.S.M.E. and assistant vice-president, American Telephone & Telegraph Company, was elected vice-chairman, and C. E. Davies, secretary, The American Society of Mechanical engineers, was elected assistant secretary. Chairmen of the Council's committees were elected as follows: Student Selection and Guidance, Robert L. Sackett, member A.S.M.E., dean of engineering, Pennsylvania State College; Engineering Schools, Karl T. Compton, member A.S.M.E., president, Massachusetts Institute of Technology; Professional Training, R. I. Rees; Professional Recognition, Conrad N. Lauer, past-president, A.S.M.E., president, Philadelphia Gas Works; Ways and Means, R. I. Rees; and Information, H. C. Parmelee, editor, *Engineering and Mining Journal*.

Members of the Executive Committee for the coming year are: J. P. H. Perry (A.S.C.E.), F. M. Becket (A.I.M.E), C. F. Hirshfeld (A.S.M.E.), L. W. W. Morrow (A.I.E.E.), H. C. Parmelee (A.I.Ch.E.), R. I. Rees (S.P.E.E.), and D. B. Steinman (N.C.S.B.E.E.).

In addition to the report of the Committee on Engineering Schools, reports of the Committees on Student Selection and Guidance and on Professional Training were approved. The report of the Committee on Professional Recognition was received and held over for discussion at a meeting to be called at some later date.

The report of the Committee on Student Selection and Guidance, of which R. L. Sackett is chairman, was devoted to the committee's studies of cooperative tests in English and mathematics with which it has been experimenting in an effort to find a reliable means of predicting a young student's ability to complete a course in engineering training. Results of attempts on the part of the Committee to encourage local groups throughout the country in intelligent selection and guidance of students were reported.

In the report of the Committee on Professional Training, R. I. Rees told of the year's work with junior engineers recently graduated from college. Successful inauguration of organized classes of study for junior engineers of the Providence Engineering Society was announced (see Mechanical Engineering, July, 1936, p. 410). It was also reported that the committee had completed its Selected Bibliography of Engineering Subjects for young engineers who wish to continue study in allied fields of engineering.

"Grandfather" Clause in New York State Engineer License Law Expires January 1, 1937

During the year ended June 30, 1936, the New York State Board of Examiners of Professional Engineers and Land Surveyors held 12 meetings and considered 4424 applications for licenses, of which 796 were rejected, 1774 held for written examination, 426 held for further consideration, 7 returned to the Department as not being eligible to file an application, and 1421 recommended for licenses.

The net amount received from fees during the fiscal year ended June 30, 1936, was $88,339.00, the expenditures were $25,524.68, leaving a surplus of $62,814.32.

During the year no charges have been submitted to the Board seeking the revocation of any license heretofore granted.

No amendments were made to the Licensing Law during the 1936 session of the Legislature. In accordance with existing provisions of the law, prior to January 1, 1937, the Board may exempt applicants for a license to practice professional engineering, if graduates of a college or school of engineering in a course registered by the Department as maintaining satisfactory standards, from any part of the examination except the written examination to establish their competency to plan, structurally design, and supervise the construction of buildings and similar structures. Every person applying subsequent to January 1, 1937, for a license as a professional engineer shall be required to pass the examination as prescribed by the Board, and to be admitted to such examination the applicant must submit evidence of graduation from a college or school of engineering registered by the Department as maintaining satisfactory standards, or must present evidence of at least 12 years of practical experience in professional engineering work of a grade and character satisfactory to the Board. The first examinations under the provisions of the law which become effective January, 1937, will be held in June, 1937. The January, 1937, examinations will be similar to the examinations given during the past few years as all applicants to be admitted to such examinations will have filed their applications prior to January 1, 1937.

C. F. Kettering to Head Patent Centennial

A nation-wide celebration of the founding, in 1836, of the present American Patent System will be held in Washington, D. C., on November 23, 1936, with Dr. Charles F. Kettering, president of the General Motors Research Corporation, serving as chairman.

The American Patent System Centennial will review the past, present, and future progress of industry and science through the inventive arts.

A tentative program calls for a meeting on the morning of Monday, November 23, in the auditorium of the building of the National Academy of Sciences, National Research Council in Washington, where invited speakers will address a selected audience. In the afternoon demonstrations will be held which will reveal new "invention babies"—new developments just at the threshold of usefulness in raising the standard of living.

In the evening a dinner for 1000 guests will be held at the Mayflower Hotel in Washington. Invitations are being extended to the local patent-law associations in the key cities of the nation to hold simultaneous local dinners.

Following brief words of comment from leaders in the industrial, legal, and governmental patent fields, the dinner guests will hear one of the two original Morse telegraph instruments receive a message from Baltimore. Thomas Edison will then address the guests in his own words from one of his early phonograph recordings.

International Conference on Letter Symbols for Heat and Thermodynamics

Delegates Present Representing Thirty-One Organizations

AN INFORMAL international conference on letter symbols for heat and thermodynamics was held in the Engineering Societies Building on September 13 and 14, 1936. At the request of the American Standards Association Sectional Committee on Letter Symbols and Abbreviations for Science and Engineering (Z-10), Dr. J. Franklin Meyer, chairman, invitations were issued by the A.S.M.E. in April, 1936, to 49 organizations in the United States and foreign countries requesting them to name delegates to represent them at the conference. It was felt that the convening of the Third World Power Conference in the United States this year afforded an excellent opportunity for such a conference since it would bring to this country many prominent scientists and engineers from abroad. The response to the invitation was satisfactory beyond expectations and 42 delegates from six countries, representing in all 31 societies and associations, were in attendance.

C. E. Davies, Secretary of the A.S.M.E., presided at the opening session of the conference held on the evening of September 13. Dr. Meyer presided at the technical sessions the following day, and H. W. Robb acted as secretary.

The calling of this conference marks another forward step toward the acceptance of a standard set of letter symbols for heat and thermodynamics. Definite progress toward the general adoption of these symbols in the United States has been made since the publication of the American Tentative Standard developed by a committee of which Dr. Sanford A. Moss was chairman. Similar lists have been published by Great Britain, 1934, Germany, 1933, and France.

The initiative for the beginning of this work in the United States was supplied by a special committee of the A.S.M.E. which was appointed in July, 1924, at the request of the A.S.M.E. Power Test Codes Committee. It consisted of Messrs. H. N. Davis, chairman; S. A. Moss, secretary; C. M. Allen; R. H. Fernald; G. A. Goodenough; F. O. Ellenwood; L. S. Marks; R. J. S. Pigott; and H. B. Reynolds. The tentative list which it proposed was later approved and published in the A.S.M.E. Power Test Code on Definitions and Values in January, 1926.

The formulation of the American Tentative Standard for Symbols for Heat and Thermodynamics was begun the same year and it was completed, approved, and published in 1931 after five years of research, revision, and discussion.

In May, 1928, a preliminary draft of this proposal was reviewed by I.E.C. Advisory Committee No. 5 on Steam Turbines at its meeting in The Hague, Holland. With slight modifications this list of symbols was incorporated in the report of this advisory committee known as I.E.C. Publication No. 46 on Steam Turbines, Part 2.

It was the purpose of the informal conference to review the differences which now exist between the several national lists and to develop a list which would represent the best possible compromise. It can be said that the September, 1936, conference was thoroughly successful. A list of symbols was tentatively approved subject to preliminary review and check by an editing committee consisting of T. N. Adlam for Great Britain, Dr. Ernest Weber for Germany, and Dr. S. A. Moss for the United States. When released by the editing committee copies of this list will be sent to all the participating organizations for their criticism and comment and it is the hope of the sponsors of the conference that this procedure will result in a still further unification of the practice in the heat-power field.

Standard Marking System for Valves and Fittings

A NEW edition of the "Standard Practice" covering M.S.S. standard marking system for valves, fittings, flanges, and unions, SP-25-1936, has just been issued by the Manufacturers Standardization Society of the valve and fittings industry.

The method of applying the general rules for marking is more specifically visualized in this new edition, by the inclusion of a number of tables definitely outlining the standard method of applying uniform markings to a wide variety of products.

Copies, priced at 50 cents each, may be secured from the society, 420 Lexington Avenue, New York, N. Y.

New A.S.T.M. Specifications

Include Ferrous and Non-Ferrous Metals; Cast Iron Defined

AT THE August 26 meeting of A.S.T.M. Committee E-10 on Standards there were approved for publication as tentative a number of new specifications recommended by A.S.T.M. committees functioning in the ferrous-metals field.

Four of the new specifications were developed and approved by Committee A-1 on Steel. These cover high-strength rivet steel (A 195), seamless-steel boiler tubes and superheater tubes for high-pressure service (A 192), alloy-steel bolting materials for high pressure at temperatures up to 1100 F (A 193) and nuts for bolts for high-pressure and high-temperature service to 1100 F (A 194). In recommending the high-strength rivet steel specifications (A 195) the Society's Steel Committee is meeting persistent demands for an authoritative specification for this material to provide for the economical use for high-strength structural steel. The steel covered is, with proper riveting technique, suitable for use with Structural Silicon Steel (A.S.T.M. Designation: A 94) and equivalent steels.

The new specifications covering seamless steel boiler tubes (A 192) provide for more rigorous and more numerous tests than in the existing A.S.T.M. Standard (A 83) covering lap-welded and steamless steel and lap-welded iron boiler tubes. The specifications cover boiler tubes and superheater tubes 2 in. in outside diameter or larger and heavier than 0.203 mininum wall thickness.

The new specifications for steel nuts (A 194) cover five grades of nut material for services varying in degree of severity: Two grades for respective service under the least exacting and most severe conditions, with three classes for use between these two extremes.

The new alloy-steel bolting material specifications for high-pressure and high-temperature service to 1100 F (A 193) cover five classes of materials: A, B, C, D, and E, class E being an austenitic steel. The minimum tensile strength, after final heat treatment, for bolting materials $2^1/_2$ in. in diameter and under, ranges from 95,000 lb per sq. in. for Class A to 135,000 lb per sq in. for Class D.

While the composition of the steel is to be agreed upon by the manufacturer and the purchaser, it may be selected from five steels listed in the body of the specifications which provide definite compositions. These steels are of the following types: Nickel-chromium-molybdenum, 4–6 per cent chromium, chromium-molybdenum, tungsten-chromium-vanadium, and tungsten-chromium. The committee has included in an appendix data relative to the chemical and physical properties of several alloy-steel bolting materials in addition to those given in the body of the specifications.

A.S.T.M. Committee A-7 on Malleable Iron Castings submitted new specifications covering malleable iron for castings made by the cupola process (A 197). The requirements provide for a minimum tensile strength of 40,000 lb per sq in., a yield point of 30,000, and minimum elongation in 2 in. of 5 per cent.

Cast Iron Defined

As the result of considerable work which has been carried out by Committee A-3 on Cast Iron, standard definitions of terms relating to cast iron have been approved as tentative (A 196). Previous definitions of Howe, Moldenke, and others were carefully reviewed and there has been voluminous correspondence with a considerable number of metallurgists all over the country. Cast iron is defined as "Iron containing so much carbon that, as cast, it is not usefully malleable at any temperature. It usually contains from 1.7 to 4.5 per cent carbon and in most cases an important percentage of silicon." An explanatory note to this definition indicates that if the iron con-

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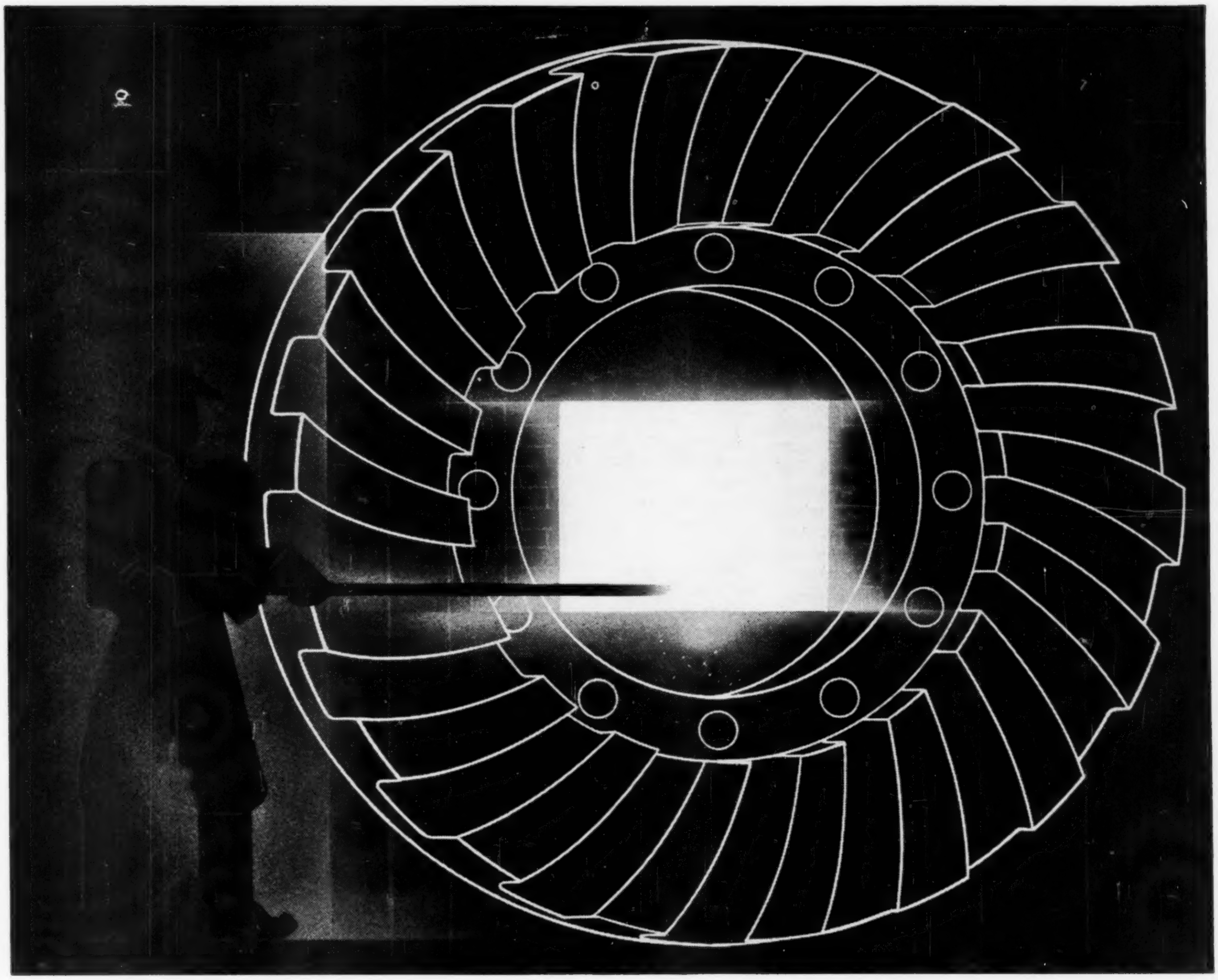

tains more than about 1.7 per cent of carbon, a residual liquid, or eutectic, is left which contains about 4 per cent of carbon and which solidifies at about 2100 F. The formation of this eutectic ledeburite is the essential difference between cast iron and steel. Gray iron is defined as: "Cast iron having a gray fracture as cast. In general it is readily machinable with ordinary tools. The combined carbon usually does not exceed 0.8 per cent, and may be much lower." White iron is "Cast iron having a white fracture. It is very hard and difficult to machine. The carbon is practically all in the form of iron carbide."

The committee in its list of definitions, which also covers mottled iron, malleable cast iron, and pearlitic malleable cast iron, indicates that semi-steel is "A vague trade name for various cast-iron products made by adding steel to the melting charge. The term never had a definite meaning and should now be considered obsolete." The committee indicates that high-test cast iron is a "term sometimes used to designate gray cast iron having a tensile strength substantially greater than that of ordinary cast iron. This term should now be considered obsolete, since the Standard Specifications for Gray-Iron Castings (A 48-36) definitely classifies gray-iron castings according to strength."

A.S.T.M. Committee E-3 on Chemical Analysis of Metals, which was organized in 1935 to take over and coordinate work formerly in the charge of the "A" and "B" groups of standing committees, presented proposed tentative methods of chemical analysis of steel, cast iron, open-hearth iron, and wrought iron (E 30). These revised methods, which are based on the experience of the members of the committee, replace the former standard methods covering chemical analysis of plain carbon steel (A 33), analysis of alloy steels (A 55), methods of sampling rolled and forged steel products for check analysis (A 130), and sampling and chemical analysis of pig and cast iron (A 64). At the same time, the committee recommended that 14 existing A.S.T.M. standards covering methods of chemical analysis of non-ferrous metals and alloys and ferroalloys should be reverted to the tentative status since Committee E-3 is working on revised methods.

Change in Specifications for Non-Ferrous Metals

The Committee E-10 on Standards also took action involving a number of items pertaining to non-ferrous metals. On the recommendation of Committee B-7 on Light Metals and Alloys new specifications for aluminum-base alloy permanent mold castings were approved. The A.S.T.M. designation B108-36T has been assigned to this new tentative standard. The specifications cover practically the entire aluminum-alloy permanent-mold field, and the committee in submitting the specifications indicated that they were representative of present practice in the field.

Extensive revisions were approved also on the recommendation of Committee B-7 involving the existing specifications for aluminum-base alloy sand castings (B 26). The changes provide the elimination of certain alloys which have become obsolete and the addition of several new alloys now in commercial production for which there has been a demand for specification requirements. Certain of the other alloys have been revised in order to bring them in line with current practice.

As a result of requests from consuming interests for more restricted specifications especially with regard to analysis requirements, Committee B-5 on Copper and Copper Alloys recommended a number of changes in four of the specifications in its charge covering copper-silicon alloy materials including plates and sheets (B 96), rods, bars and shapes (B 98), wire (B 99), and sheet alloy (B 97).

New York Management Council to Hold Series of Business- and Industrial-Management Meetings

THE New York Management Council has announced a series of joint meetings on business and industrial management to be held monthly from September, 1936, to May, 1937. These meetings are held in the auditorium of Metal Products Exhibits, International Building, Rockefeller Center, New York.

Registration fee to members of participating societies is fifty cents. Guests presenting tickets signed by members will be charged seventy-five cents; college students, twenty-five cents.

Its Purpose

It was at the suggestion and with the cooperation of the National Management Council that the New York Management Council was organized in the spring of 1936 by representatives of New York Sections of several management societies.

Its purpose is the establishment of an informal organization through which local societies and local sections of national societies, concerned with various aspects of business and industrial management, cooperate in promoting the mutual interests of their members.

With increasing specialization on numerous functions of management, it is of utmost importance that all phases be harmoniously integrated and intelligently controlled.

Members of all societies participating in the New York Management Council project and their invited guests have an opportunity to make helpful social and business contacts outside of the specialty in which each is engaged; an opportunity to participate in the discussion of timely subjects presented by outstanding authorities; an opportunity to tell and to learn for what each in his particular specialty is striving.

Participants

The New York Management Council is affiliated with the National Management Council on a mutual advisory basis. It functions solely through delegation of authority by representatives elected or appointed by its participating societies and will in no way impair the individual identity of any of these organizations. By applying a nominal registration fee at joint meetings sponsored by the N.Y.M.C. but conducted by participating societies in the Council, the N.Y.M.C. is to be self-supporting.

The following societies and associations are now participating in the N.Y.M.C. project: American Institute of Accountants; American Institute of Consulting Engineers; American Management Association; American Marketing Society; American Psychological Association, Inc.; The American Society of Mechanical Engineers; Association of Consulting Management Engineers; Econometric Society; Greater New York Safety Council; International City Managers Association; Life Office Management Association; Market Research Council; National Association of Cost Accountants; National Federation of Sales Executives; National Office Management Association; New York Credit Men's Association; New York Society of Architects; Personnel Research Federation; Purchasing Agents Association of New York; Management Division, Real Estate Board of New York; Sales Executives Club of New York; Society for the Advancement of Management; Society for the Promotion of Engineering Education; Trade Association Executives in New York City.

G. W. Kelsey Elected Chairman

At the organization meeting, George W. Kelsey, president of G. W. Kelsey & Company, and chairman of the Management Division of The American Society of Mechanical Engineers, was elected chairman; Walter K. Porzer, of Lambert & Feasley, and president of the New York Chapter of the Society for the Advancement of Management, was elected secretary; and John W. Riedell, treasurer of the recording and Statistical Corporation, and president of the New York Chapter of the National Office Management Association, was elected treasurer.

Middle Atlantic Section of S.P.E.E. Meets at Columbia, on December 5

ON Saturday, December 5, the fall meeting of the Middle Atlantic Section of the Society for the Promotion of Engineering Education will be held at Columbia University. Members and women guests from other sections of the S.P.E.E. are cordially invited to attend.

A copy of the program may be had by addressing Dean J. W. Barker, who is chairman of the local committee of arrangements at Columbia University, or Prof. F. L. Eidmann, of Columbia University, who is chairman of the Middle Atlantic Section.

(*A.S.M.E. News continued on page 768*)


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"PALCO" — Selected cotton of great tensile strength. Lubricated in each single strand before plaiting. Centrifugal, reciprocating and mine pumps. Keeps water in—keeps air out. Will not score shaft of high-speed centrifugal pump. Not affected by feed-water-treating compounds.
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"SUPER-CUTNO" — Heavy acids, hydrochloric, nitric, phosphoric, sulphuric and similar acids. Selected hornblende asbestos; with lubricating compound to resist cutting tendency of acids, especially at elevated temperatures.
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"PELRO" — Lubricant unaffected by solvents, insuring proper lubrication of pump and mixer shafts, avoiding over-heating and friction. For gasoline and cold solvents, cut lap-bevel rings, with no allowance for expansion.
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AMERICAN ENGINEERING COUNCIL'S EXHIBIT AT WORLD POWER CONFERENCE

"Engineering Organization in the United States"

"ENGINEERING Organization in the United States," a pamphlet prepared by the American Engineering Council for distribution to the delegates to the Third World Power Conference, contains descriptions of each of the functional organizations, lists the name, the secretary, membership, and principal activities of 53 national engineering societies, 40 state organizations, and 96 local organizations. It contains also a brief article entitled "Why the Engineer?" contributed by Dr. William F. Durand, chairman of the Third World Power Conference, John Fritz Medalist for 1935, and past-president and honorary member of the A.S.M.E. Greetings from the engineers of the United States to the delegates are conveyed in this brochure.

The printing of the pamphlet was made possible through the courtesy of the Washington Society of Engineers. A limited number are available for distribution to those who ask for copies. Requests should be addressed to the American Engineering Council, 744 Jackson Place, Washington, D. C.

Candidates for A.S.M.E. Membership

THE application of each of the candidates listed below is to be voted on after November 25, 1936, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member having comments or objections should write to the secretary of the A.S.M.E. at once.

NEW APPLICATIONS

Austin, C. T., Altadena, Calif. (Re)
Baer, Clarence L. H., Washington, D. C.
Bass, Jas. S., Jr., Spencer, N. C.
Bell, J. B., Birmingham, Ala.
Brauninger, Glen G., Kansas City, Mo.
Brockman, Fred W., Baltimore, Md. (Re)
Buchanan, J. E., Charlotte, N. C.
Cannon, C. Newton, Swampscott, Mass.
Daniels, A. N., Hancock, N. H.
De Santis, Faust G., Worcester, Mass.
Dueringer, Walter E., Cleveland, Ohio
Duffy, Edward C., Brooklyn, N. Y.
Fassett, Donald G., Seattle, Wash.
Foote, F. D., New York, N. Y.
Fornes, Gaston G., Raleigh, N. C.
Friedman, Sidney C., Springfield, Mass.
Grasso, Louis A., Pittsburgh, Pa.
Halpern, Herman, New York, N. Y.
Hazelton, Merrill W., Beloit, Wis.
Hedge, Jesse G., Oakland, Calif.
Henig, Ludwig, Titusville, N. J.
Hilli, Richard A., Indian Orchard, Mass.
Kisa, Oscar A., Milwaukee, Wis.
Ledden, Edward B., Newark, N. J.
Lingner, George L., Woodcliff, N. J.
McHugh, Carl M., Spencer, N. C.
Mellon, G. W., Brooklyn, N. Y.
Murphy, Tarver S., Jr., Tulsa, Okla.
Perry, Harold G. B., Shanghai, China
Peterson, Ivan L., Cleveland, Ohio
Poletika, Peter N., Wilkinsburg, Pa.
Powell, Edwin D., Spencer, N. C.
Rowand, Will Haines, New York, N. Y.
Sheppard, Wm. L., Philadelphia, Pa.
Short, Merle K., Moline, Ill.
Speciall, Joseph V., Sunnyside, L. I., N. Y.
Tatham, W. C., Springs Transvaal, South Africa
Thompson, W. L., Washington, D. C.
Thomson, Robert S., Richmond Hill, L. I., N. Y.
Wagner, Robert L. Niagara Falls, N. Y.
Workman, Ross F., Reno, Nevada

CHANGE OF GRADING

Transfers from Junior

Anderson, K. B., Oakland, Calif.
Hummel, J. O. P., State College, Pa.
Hungate, L. H., Jr., Memphis, Tenn.
Johnson, Charles Lewis, Charleston, W. Va.
Knowlton, P. H., Jr., Schenectady, N. Y.
Sevilla, Gregorio J., Pasay, Rizal, P. I.
Schmidt, John H., Chicago, Ill.
Svenson, Prof. Carl L., Cambridge, Mass.

Necrology

THE following deaths of members have recently been reported to the Office of the Society:

Arbogast, Victor R., May 27, 1936
Bartlett, George M., September 17, 1936
Burgoon, Charles E., September 20, 1936
Dunn, Charles W., September 8, 1936
Goeser, Edwin W., January 21, 1936
Hamilton, Alex. K., September 8, 1936
Kielblock, William, August 25, 1936
Le Chatelier, Henri, September 18, 1936
Lewis, Rollin C., March 23, 1936
Nygren, Werner, August 29, 1936
Patterson, Thomas, July 24, 1936
Wagner, Hugh K., July, 1936

A.S.M.E. Transactions for October, 1936

THE October, 1936, issue of the Transactions of the A.S.M.E. contains the following papers:

Welding Design (MSP-58-1), by C. H. Jennings
Welding Alloy Steels (MSP-58-2), by A. B. Kinzel
Arc Welding of Structural Alloy Steels (MSP-58-3), by W. L. Warner
Rolled Steel in Machine Construction (MSP-58-4), by H. G. Marsh
Welding Heavy Machinery (MSP-58-5), by C. A. Wills and F. L. Lindemuth
Applications of Copper-Alloy Welding (MSP-58-6), by I. T. Hook
The Electric Welding of Monel and Nickel (MSP-58-7), by F. G. Flocke and J. G. Schoener
The Welding of Aluminum Alloys (MSP-58-8), by G. O. Hoglund
Casting or Welding in Machine Design (MSP-58-9), by J. L. Brown
Hydraulic-Laboratory Projects of the Corps of Engineers, U. S. Army (HYD-58-2), by F. H. Falkner
American Hydraulic-Laboratory Practice (HYD-58-3), by L. J. Hooper
History and Present Status of Research and Specifications of Diesel Fuel Oil (OGP-58-2), by A. E. Becker and M. J. Reed